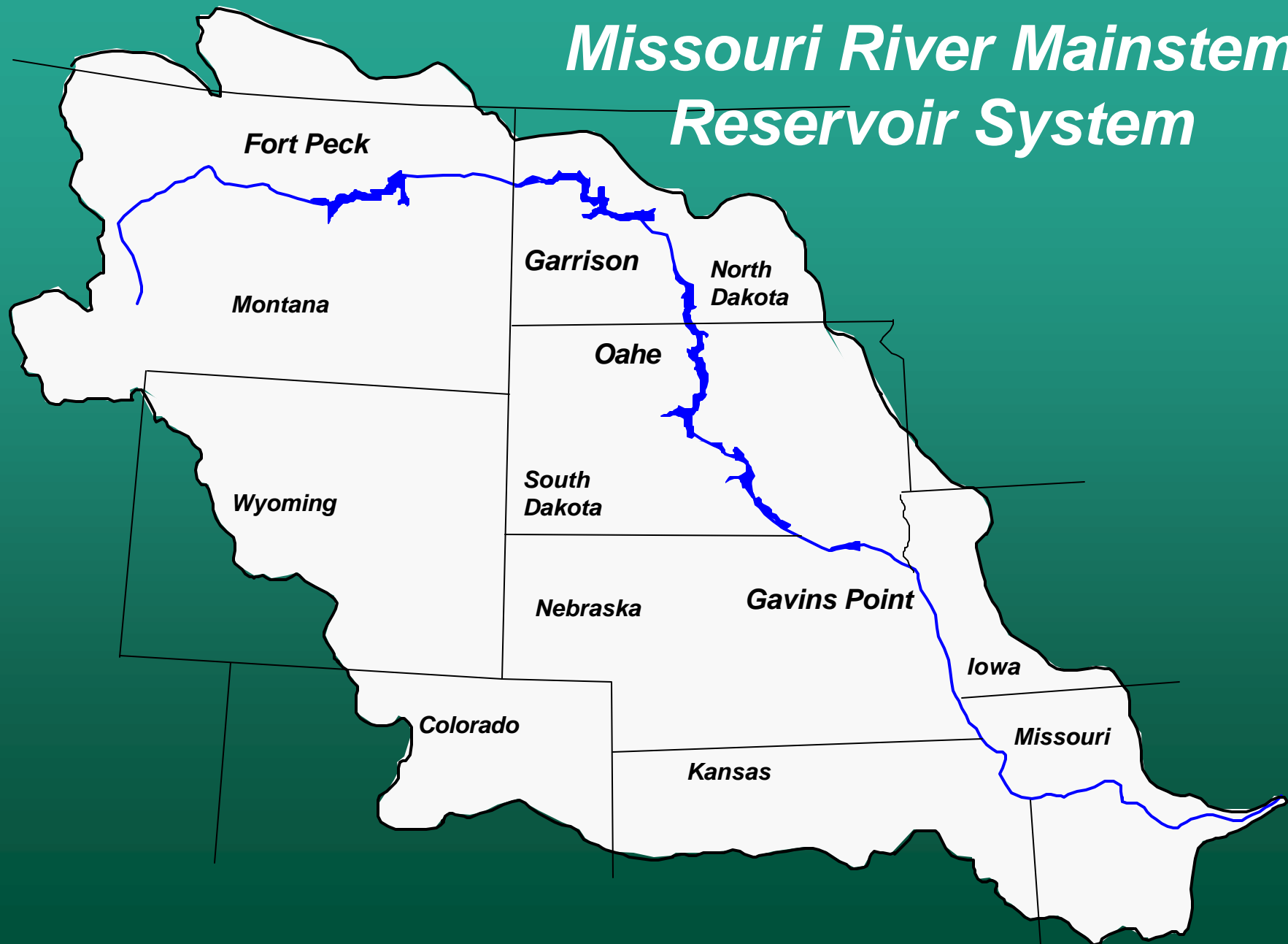


Republican River Compact Settlement and Groundwater Model

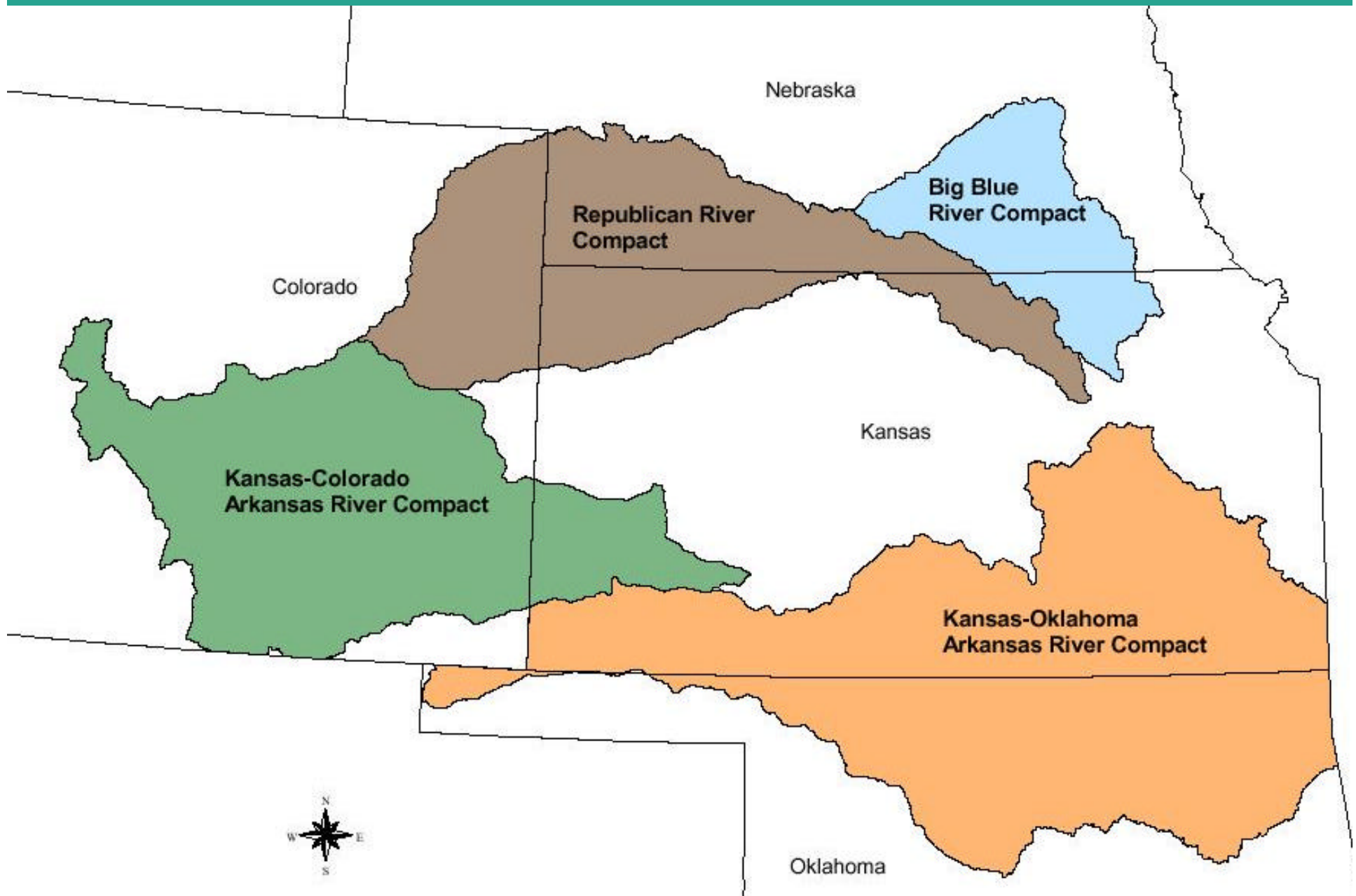
**David Barfield, Interstate Water Issues
KDA, DWR**

**2003 Kansas Hydrology Seminar
November 21, 2003**

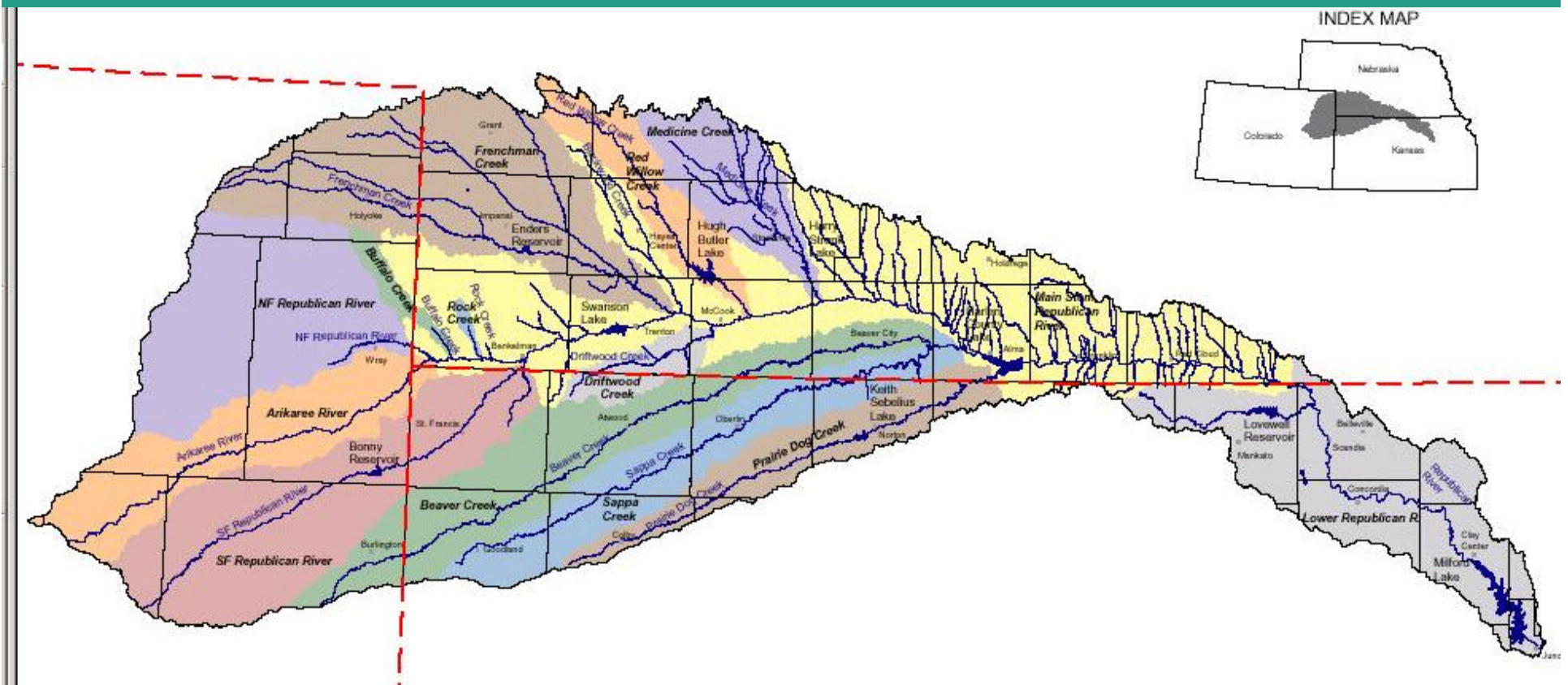
Missouri River Mainstem Reservoir System



Kansas Water Compacts



Republican River Basin



Republican River Compact negotiation motivated by:

Drought of the 1930's

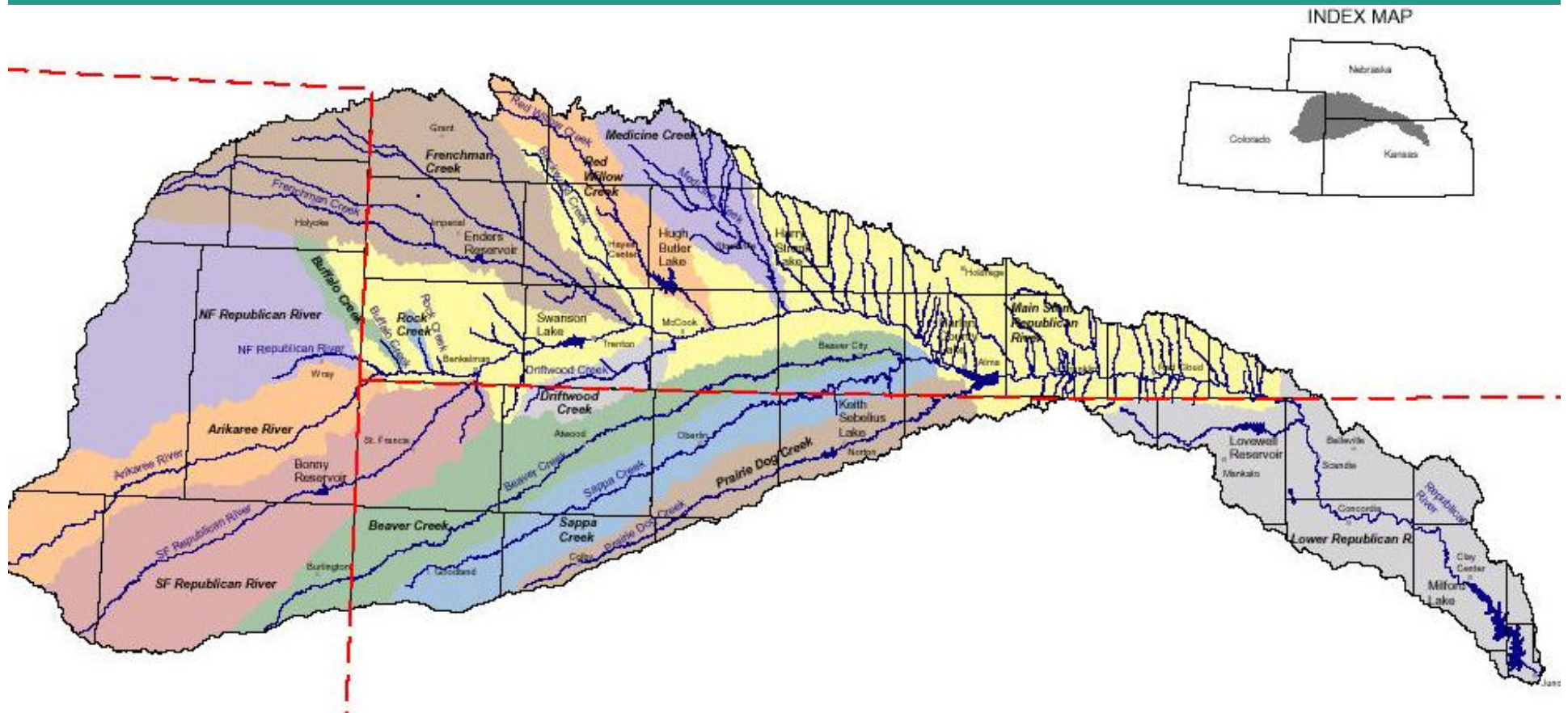
1935 Flood



Compact Framework

- The negotiators estimated the Basin's water supply and allocated 100 % of it to the States by major tributary (sub-basins).
 - Nebraska: 234,500 AF
 - Colorado: 54,100 AF
 - Northwest KS tributaries: 52,300 AF
 - KS main stem, 138,000 AF

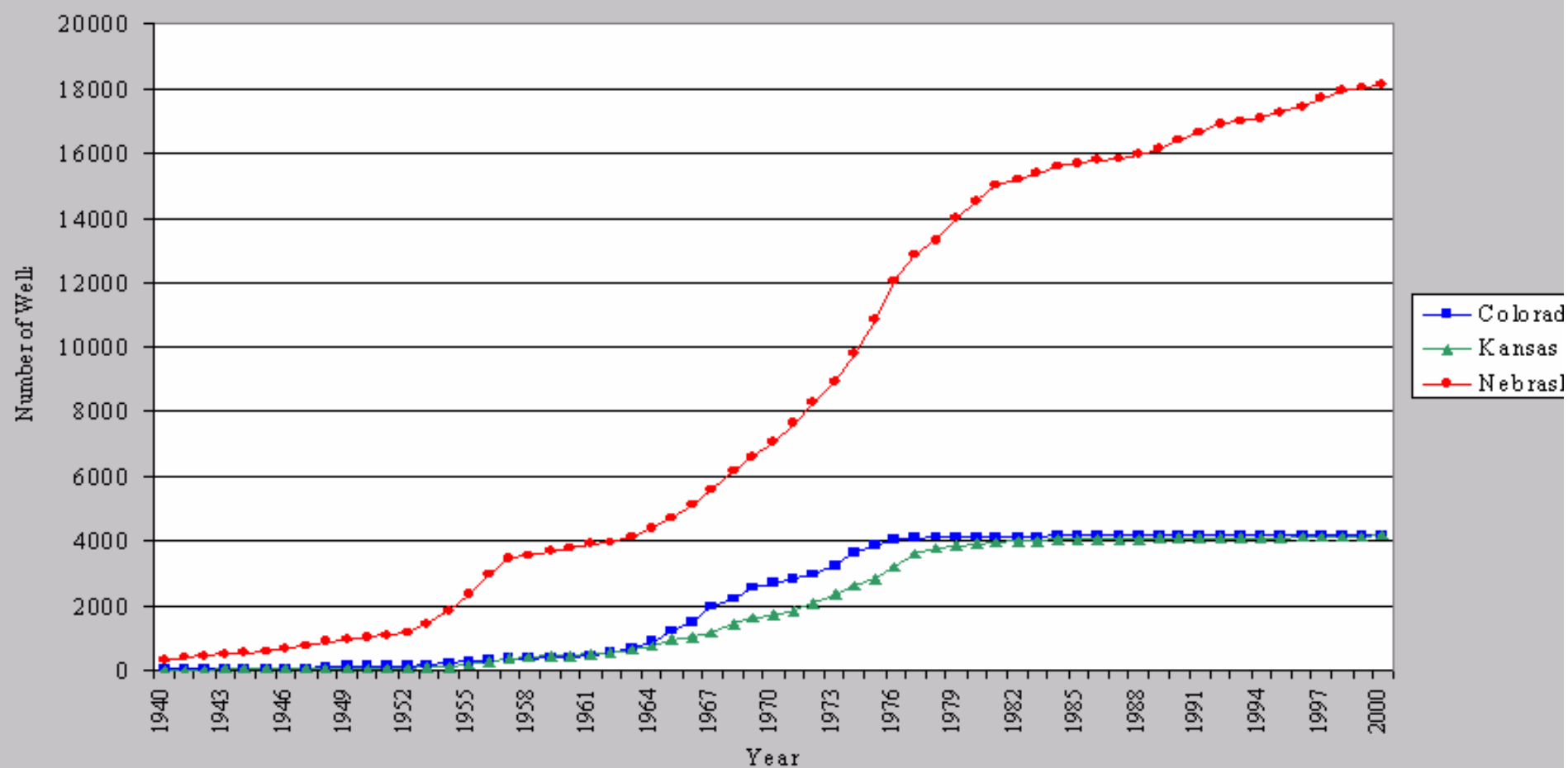
9 Federal reservoirs built 6 Irrigation districts



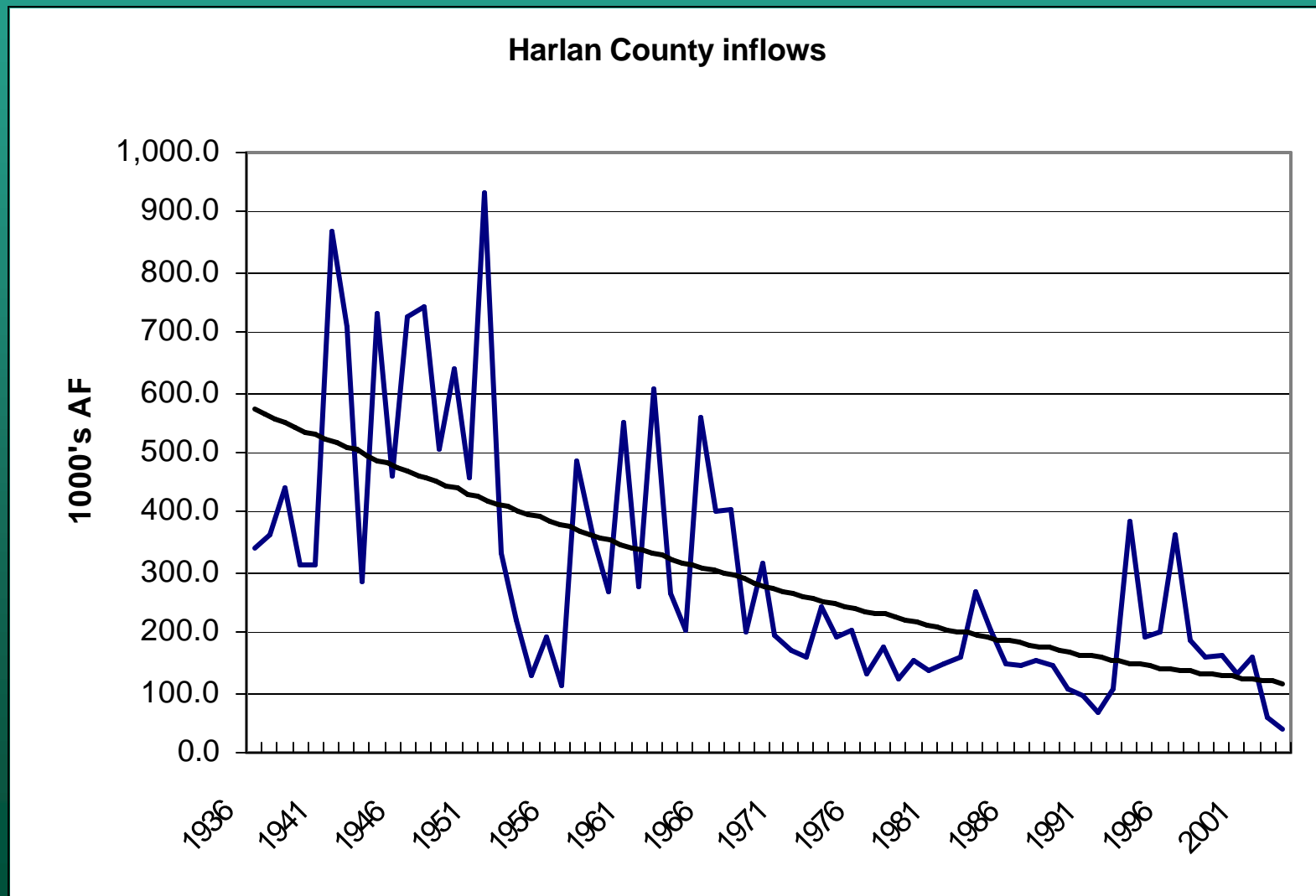
Kansas concerns

- Beginning in the 1980's, Kansas raised two primary concerns regarding the Compact:
 - Nebraska's failure to comply with the Compact primarily through inadequate regulation of groundwater
 - The lack of enforcement of the Compact.

Cumulative Number of Active Wells in the Republican River Model Domain



By the late 1970's, significant shortages began to occur



Initiation of the lawsuit

During May 1998, after the failure of repeated failures to resolve its concerns through the Compact Administration, Kansas filed suit against Nebraska in the U.S. Supreme Court.

Settlement discussions

- October 2001 - States began settlement negotiations.
- December 2002 - States reach the settlement, requiring the completion of joint groundwater model.
- July 2003 - States agreed on the joint groundwater model.
- October 2003 – Court's final action.

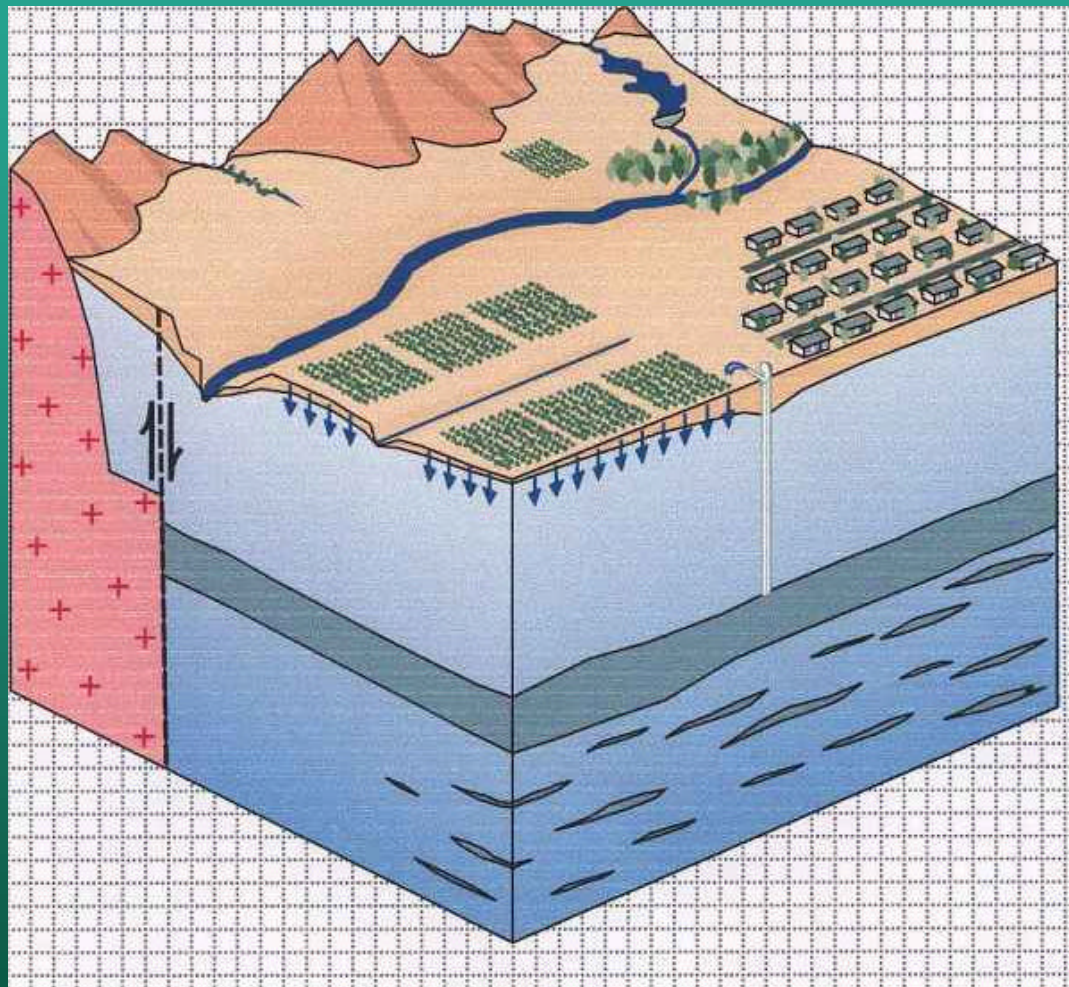
Settlement documents

- The final settlement documents comprise over 700 pages including:
 - The Final Settlement Stipulation
 - 78 pages of detailed accounting procedures
 - Agreement on principles governing of the completion of the RRCA groundwater model.

Settlement summary

- The Settlement provides clear and binding rules for future administration of the Compact.
- In settling the case, the States found a careful balance of flexibility for upstream uses and the needs of downstream uses, within the constraints of the Compact's framework.

The RRCA Groundwater Model



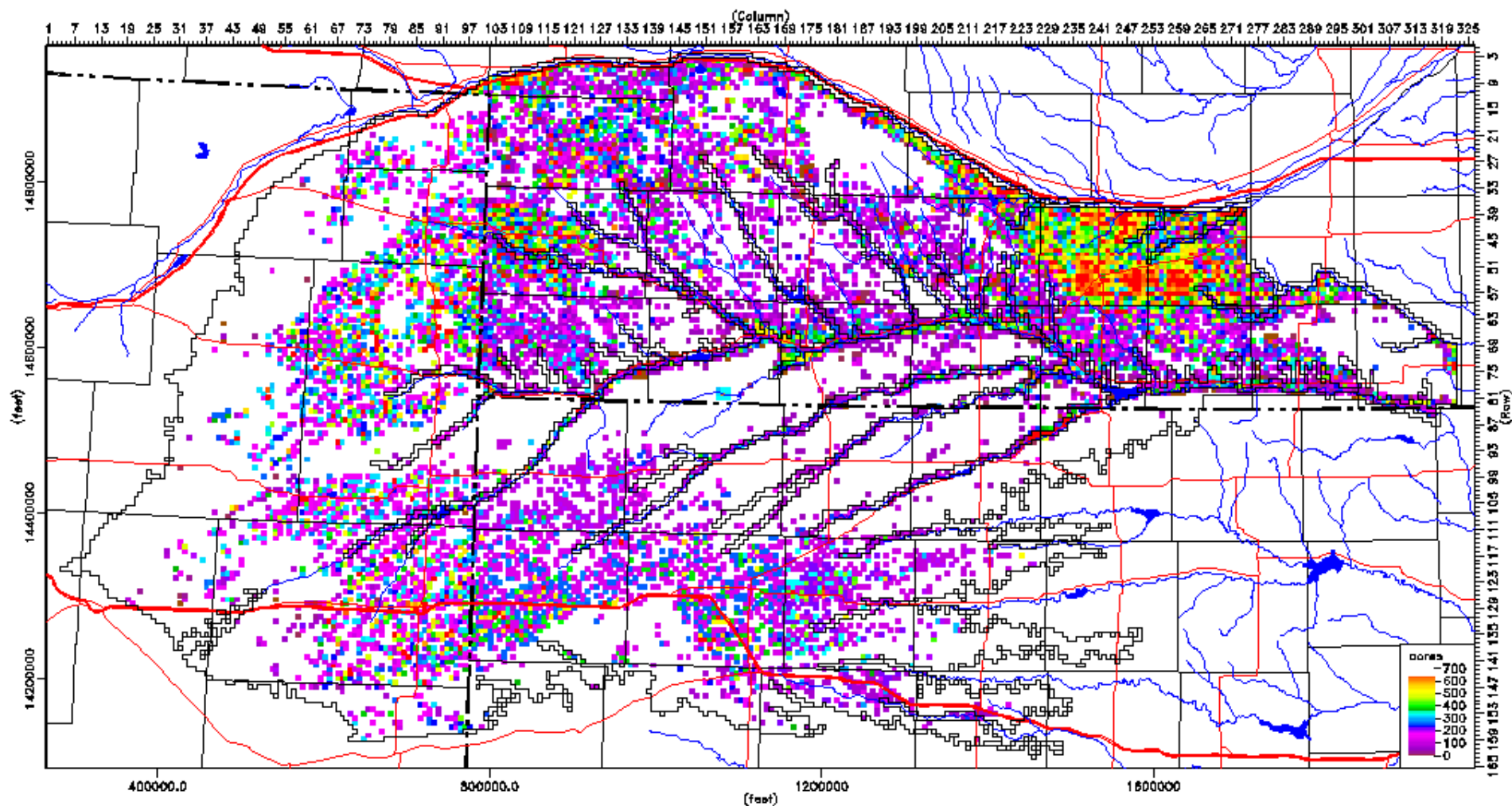
Groundwater model purposes

- The Settlement required the completion of a jointly developed computer model to determine in the annual Compact accounting:
 - Streamflows depletions by groundwater pumping, **including from Ogallala wells**
 - Streamflow accretions from Platte River imports.



Irrigated Acres 2000

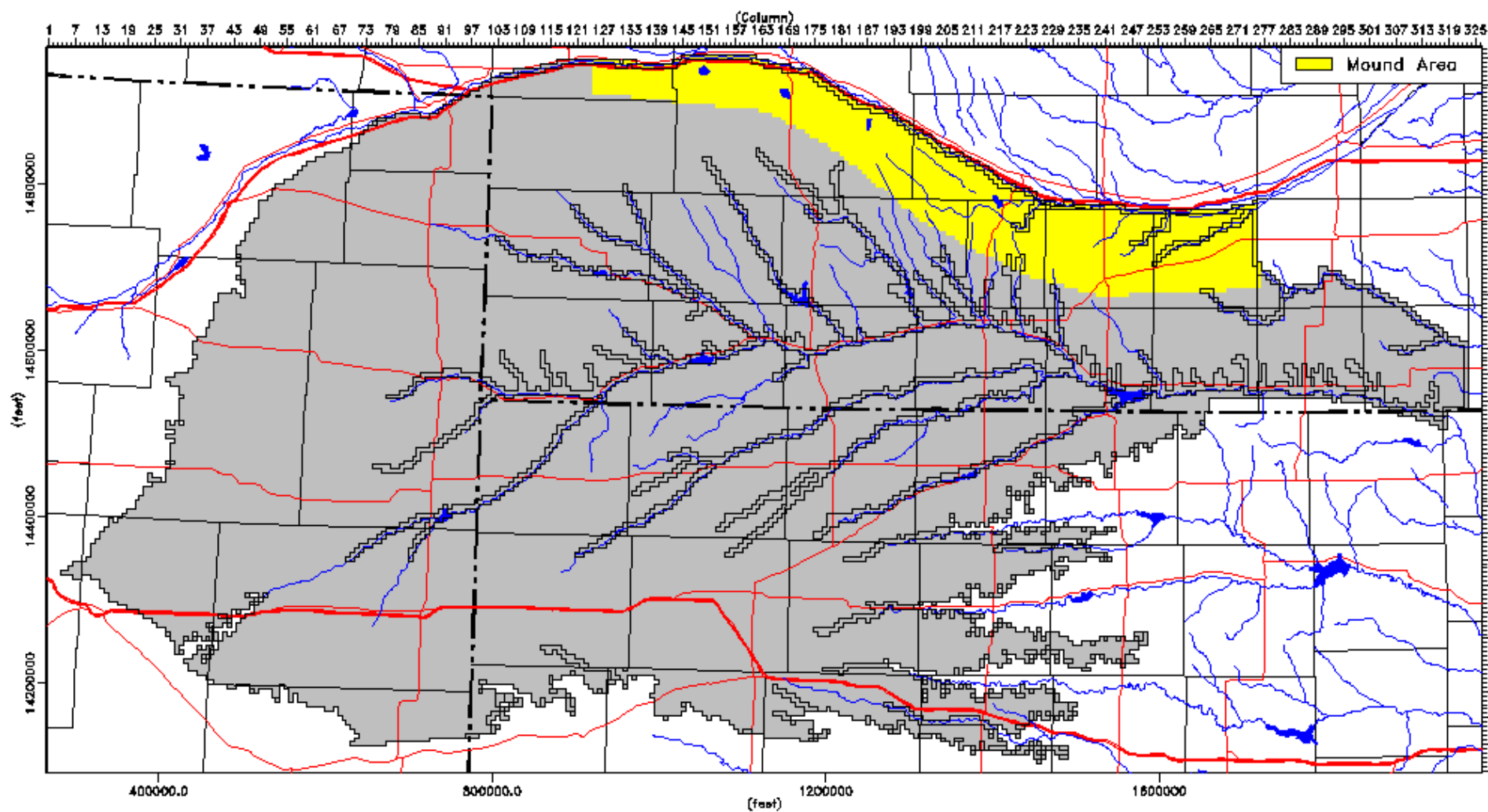
Republican River Settlement Model Version 12p





Mound Area

Republican River Settlement Model Version 12p



Groundwater CU determination in historic Compact methods

GW CU = alluvial pumping

– 25% return flows

No Ogallala effects considered

No consideration of groundwater
storage ?

Use of RRCA groundwater model in compact accounting

- Model determines impacts of Ogallala pumping, aquifer storage change (timing), and the impact of ? phreatophyte ET.
- As over 60% of the water use in the Basin is due to groundwater pumping impacts, the model's development was of critical interest to all states.

RRCA groundwater model development

- The model was developed through the combined efforts of each state's technical staff and consultants.
- The States began with a USGS model under development as the work began.
- MODFLOW2000. Single layer.
- 1 square mile grid cells.
- Simulated 1918 to 2000.

Uniqueness of the model

- Focus on impacts of pumping on streamflow.
- An order of magnitude more baseflow data and examination than most models (65 stations; 1000's of station-months of data).
- Very significant peer review through experts of the states.
- Will be used annually to determine compliance with the Compact.

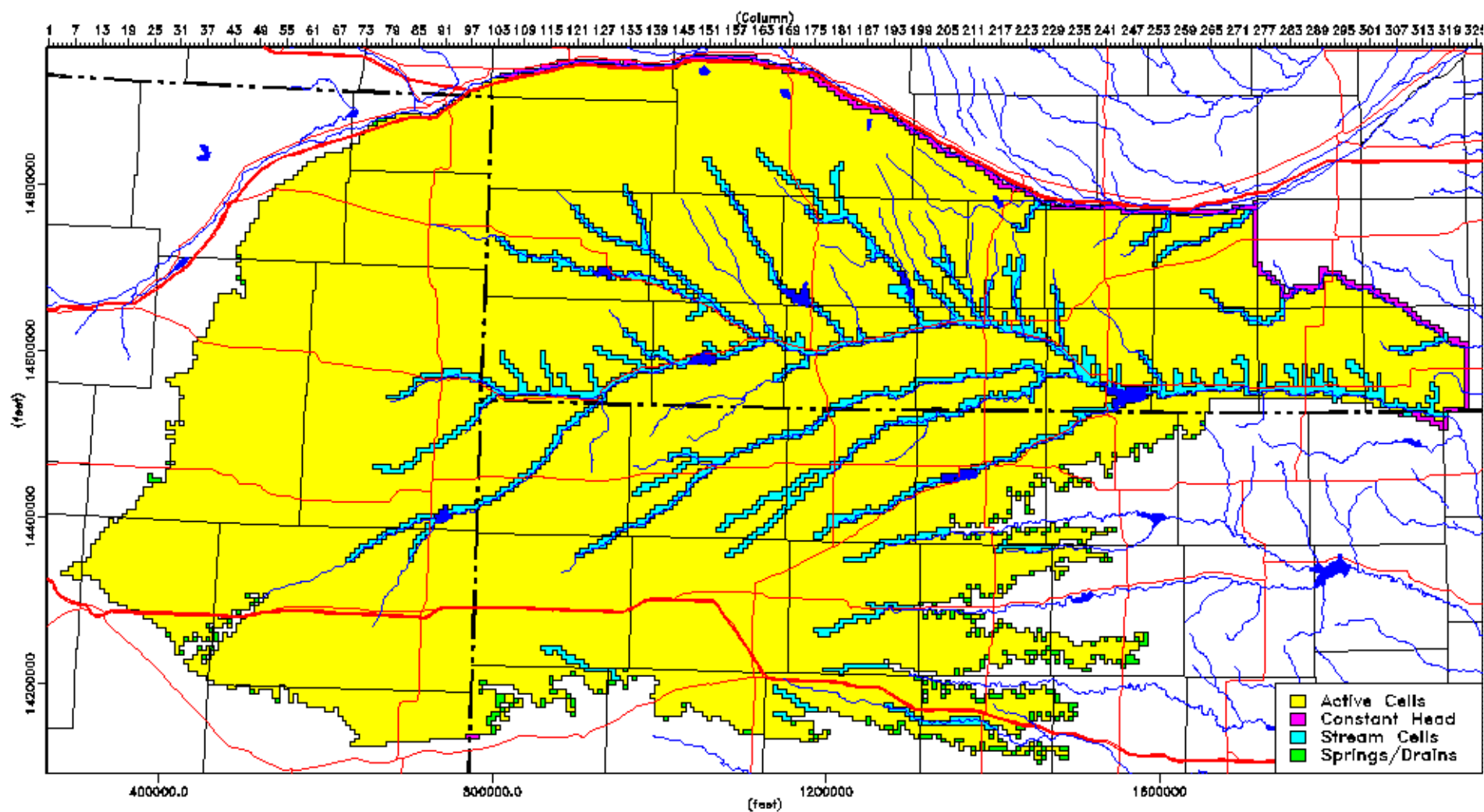
Model structure / Predevelopment inputs

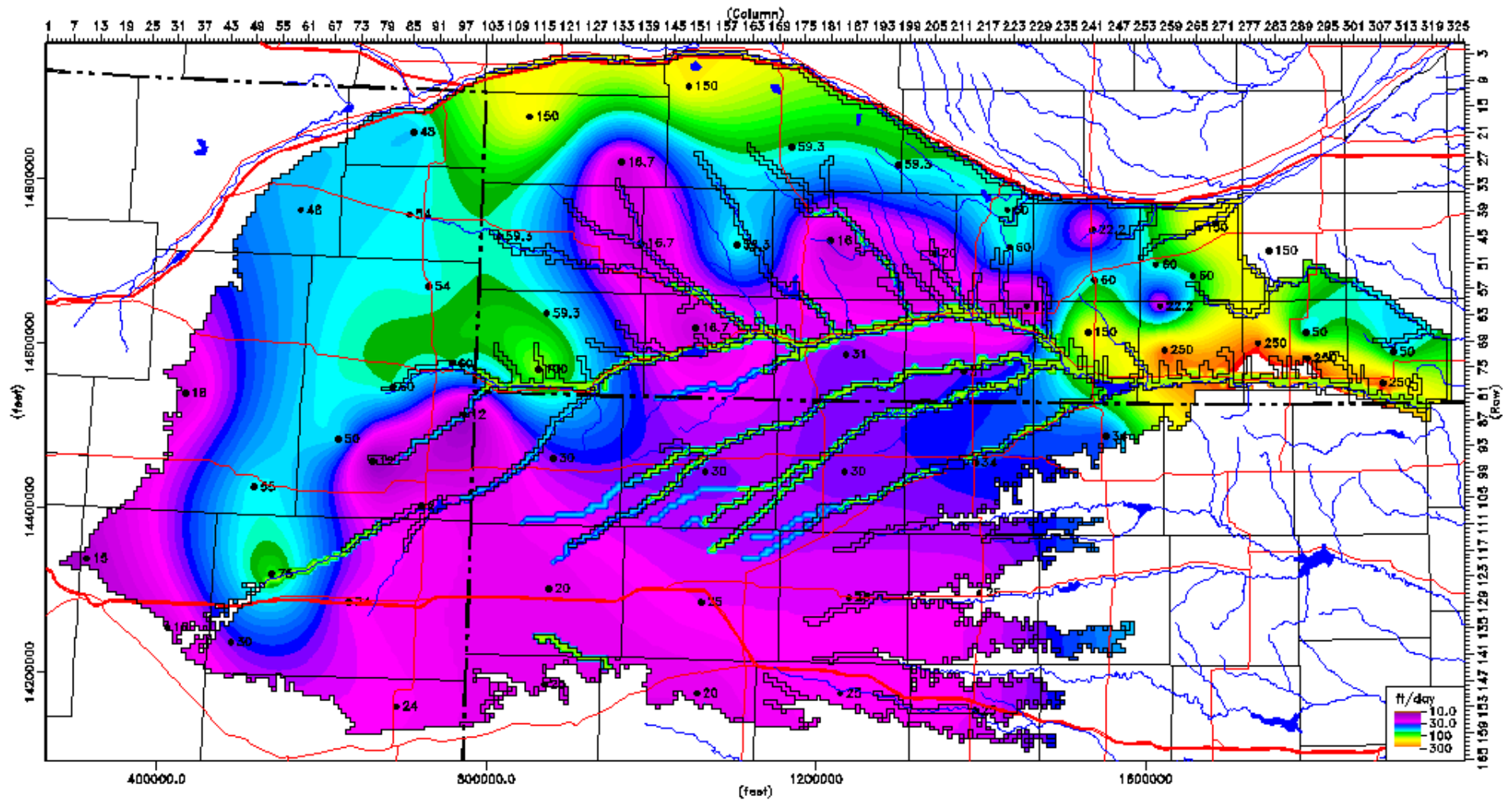
- Model domain / cell types
- Aquifer properties
- Predevelopment inflows
 - Precipitation recharge
- Predevelopment outflows
 - Baseflows/drains
 - Phreatophyte ET



Ground Water Model Domain

Republican River Settlement Model Version 12p

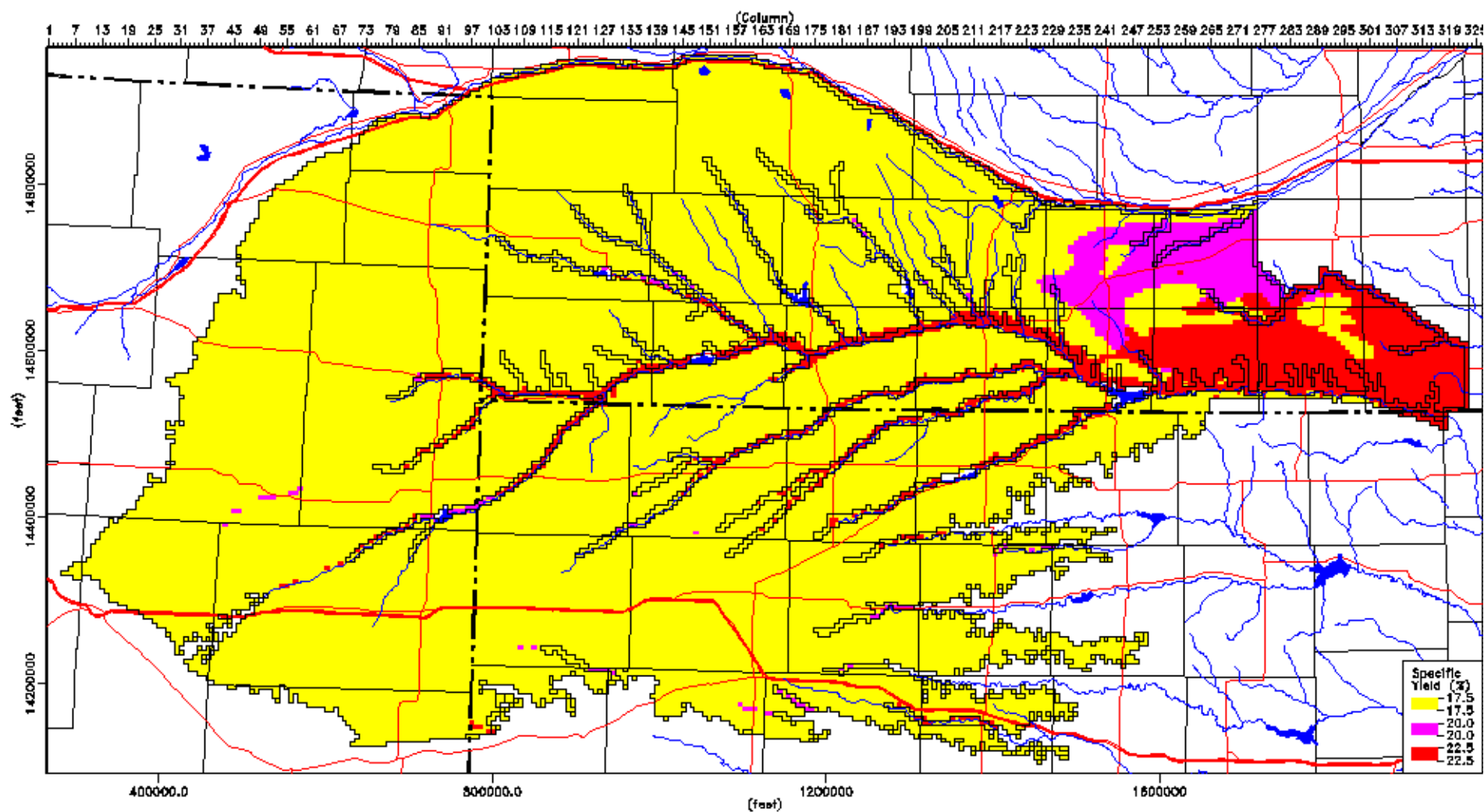






Distribution of Specific Yield

Republican River Settlement Model Version 12p



Groundwater inflows

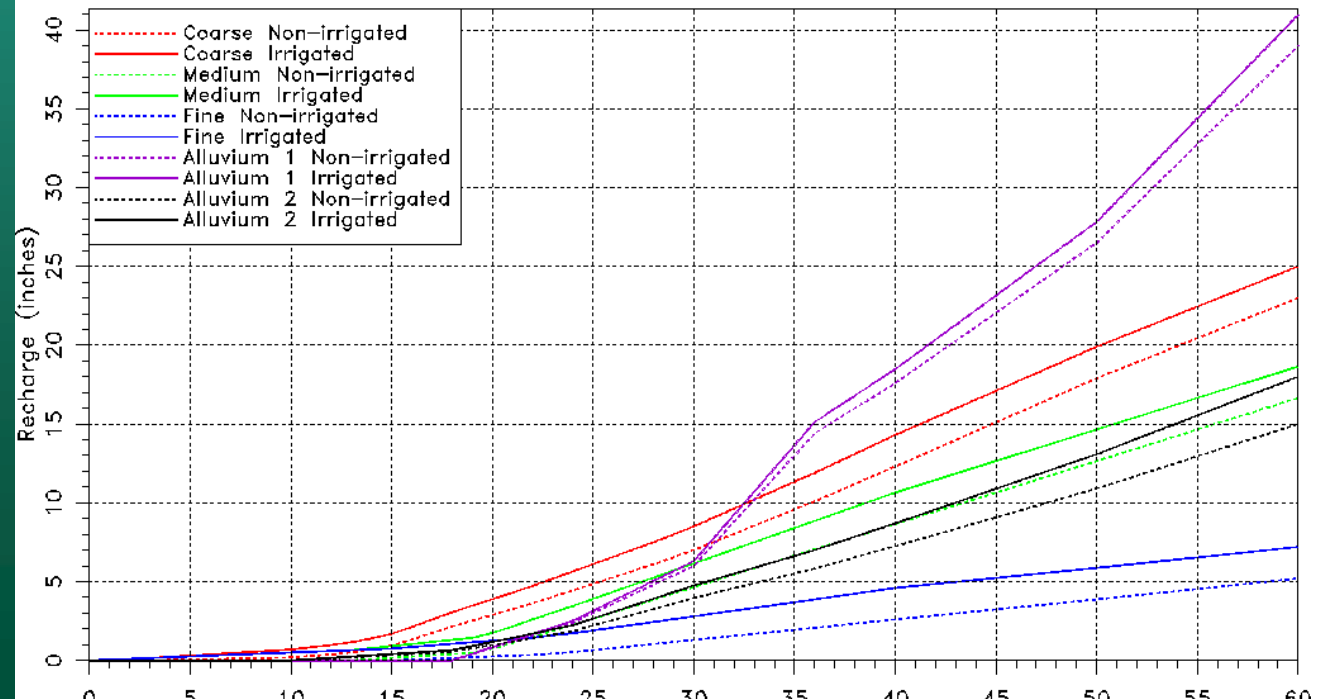
Precipitation Recharge

- Dominant groundwater system inflow.
- Estimated as a function of soil type, precipitation and whether irrigated.



Precipitation Recharge Curves

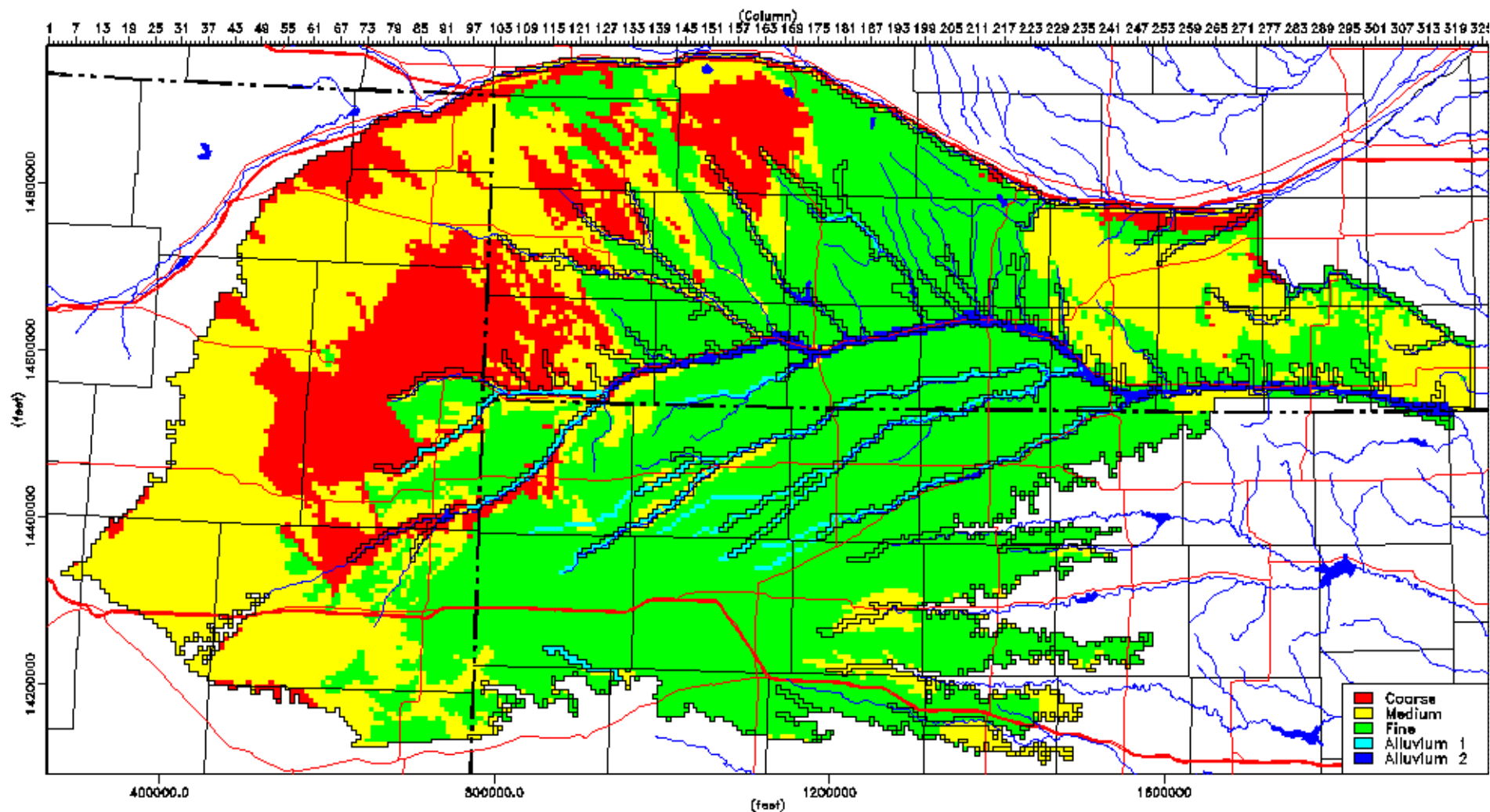
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Soil Types

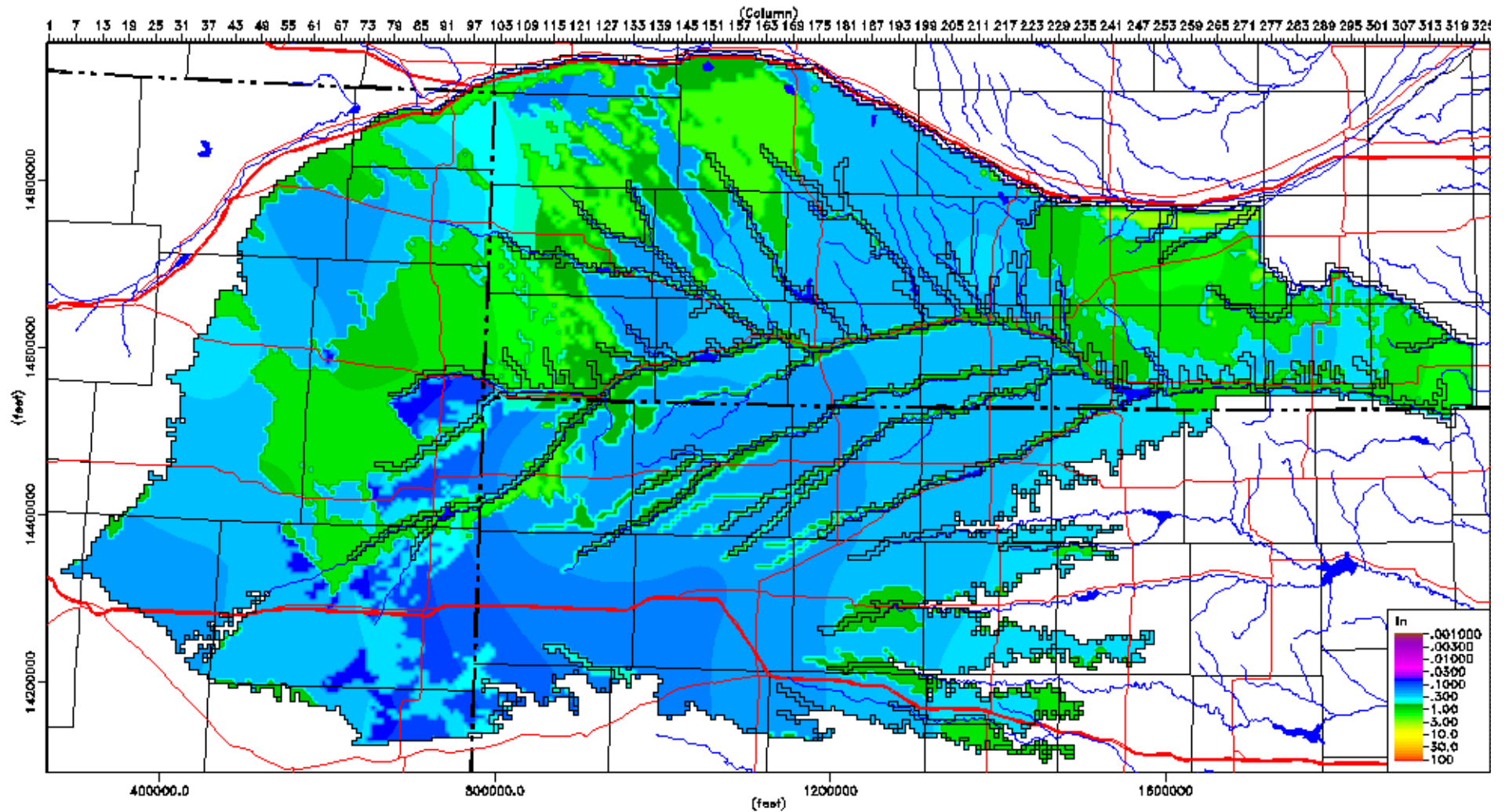
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Recharge Steady State

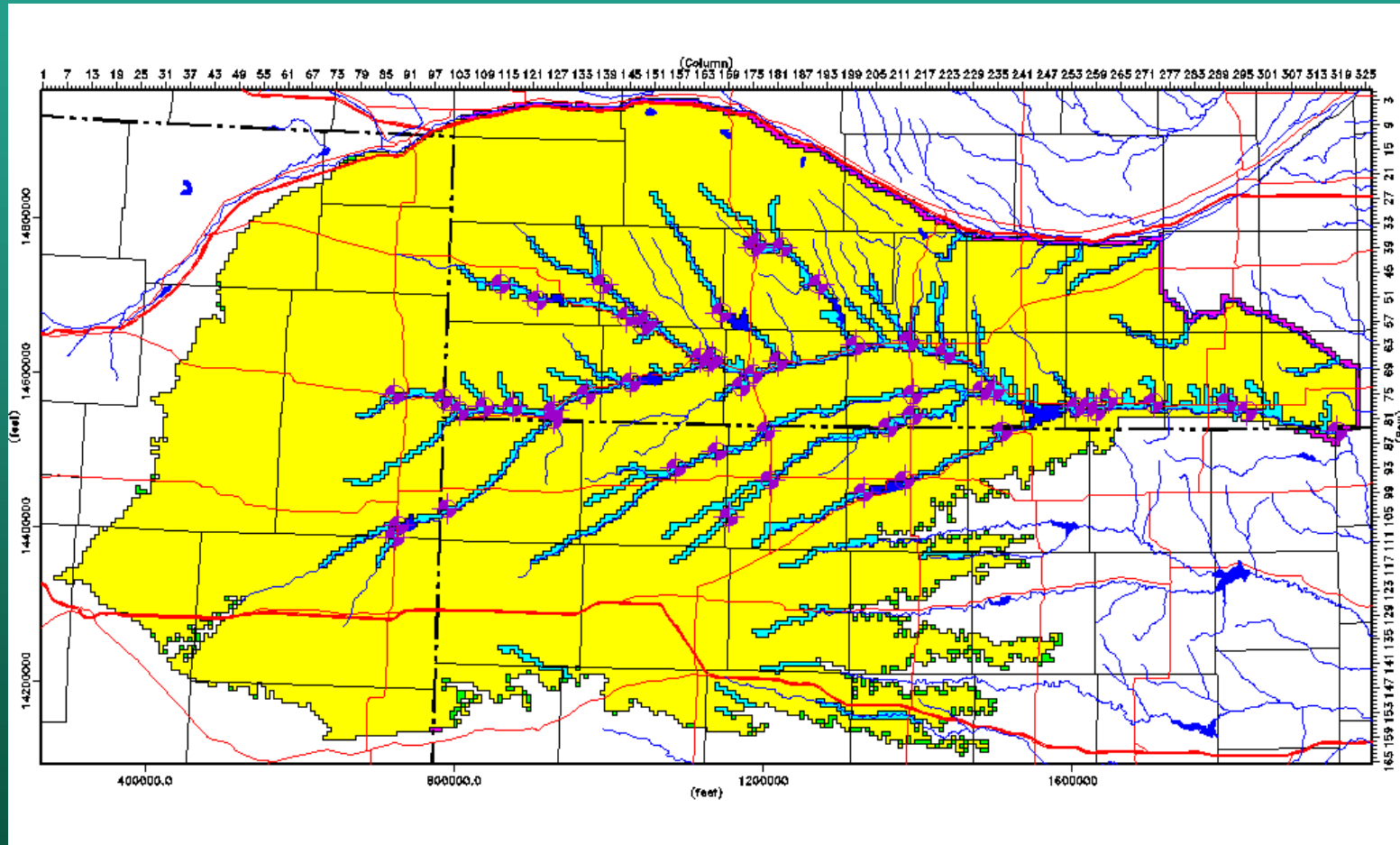
Republican River Settlement Model Version 12p



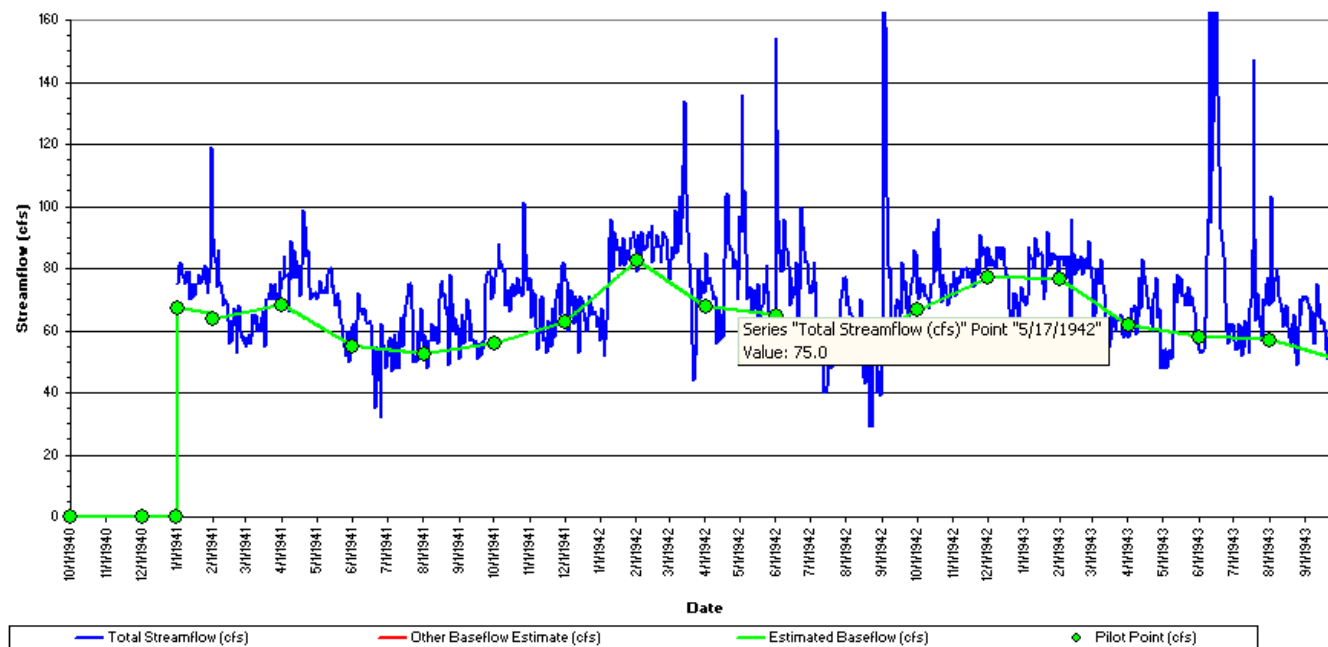
Groundwater outflows Streams/Drains

- Baseflows taken as groundwater system outflows.
- Baseflow separations completed by the committee at 65 locations.

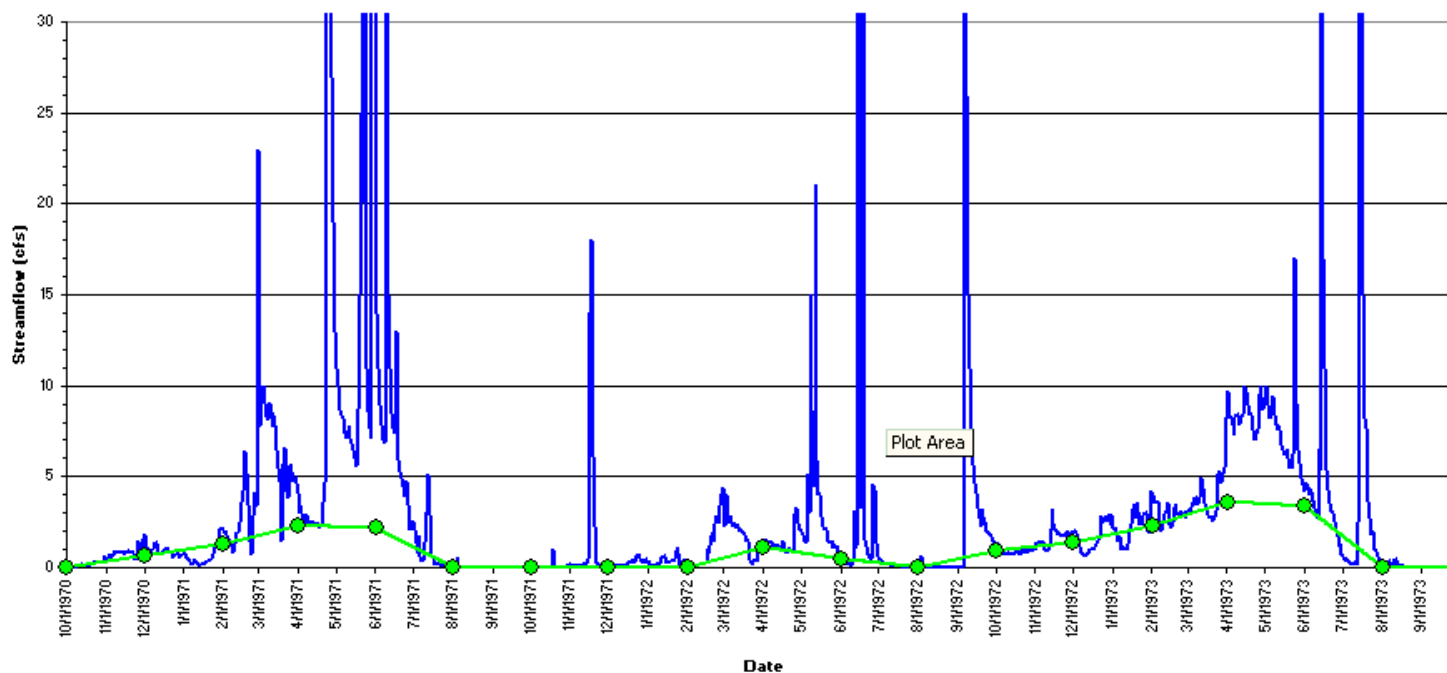
Baseflow locations



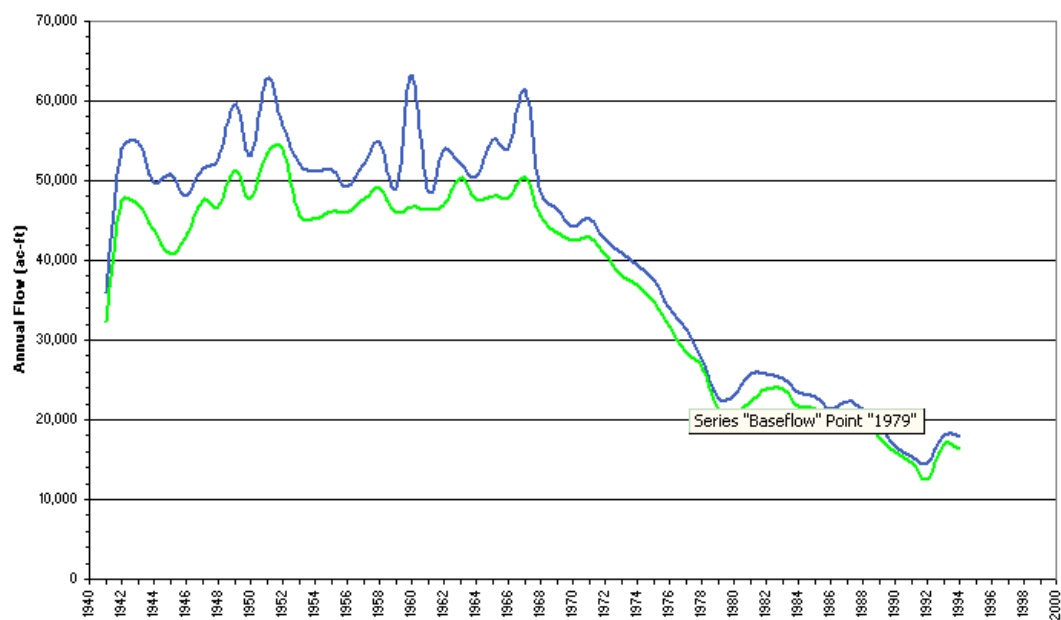
Estimated Baseflow - Frenchman Creek near Imperial, Ne (6831500)



Estimated Baseflow - Prairie Dog Creek above Keith Sebelius Lake, Kan. (6847900)

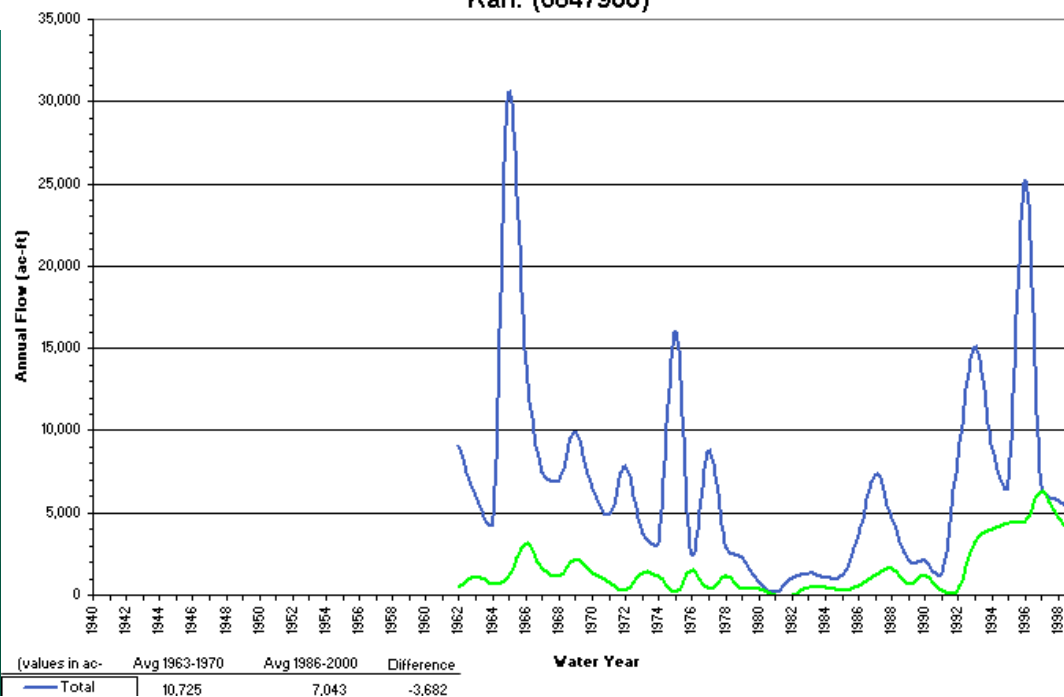


Estimated Baseflow - Frenchman Creek near Imperial, Ne (6831500)



(values in ac-)	Avg 1950-1964	Avg 1986-1994	Difference
Total	53,390	18,552	-34,838
Baseflow	47,952	17,278	-30,674

Estimated Baseflow - Prairie Dog Creek above Keith Sebelius Lake, Kan. (6847900)



(values in ac-)	Avg 1963-1970	Avg 1986-2000	Difference
Total	10,725	7,043	-3,682

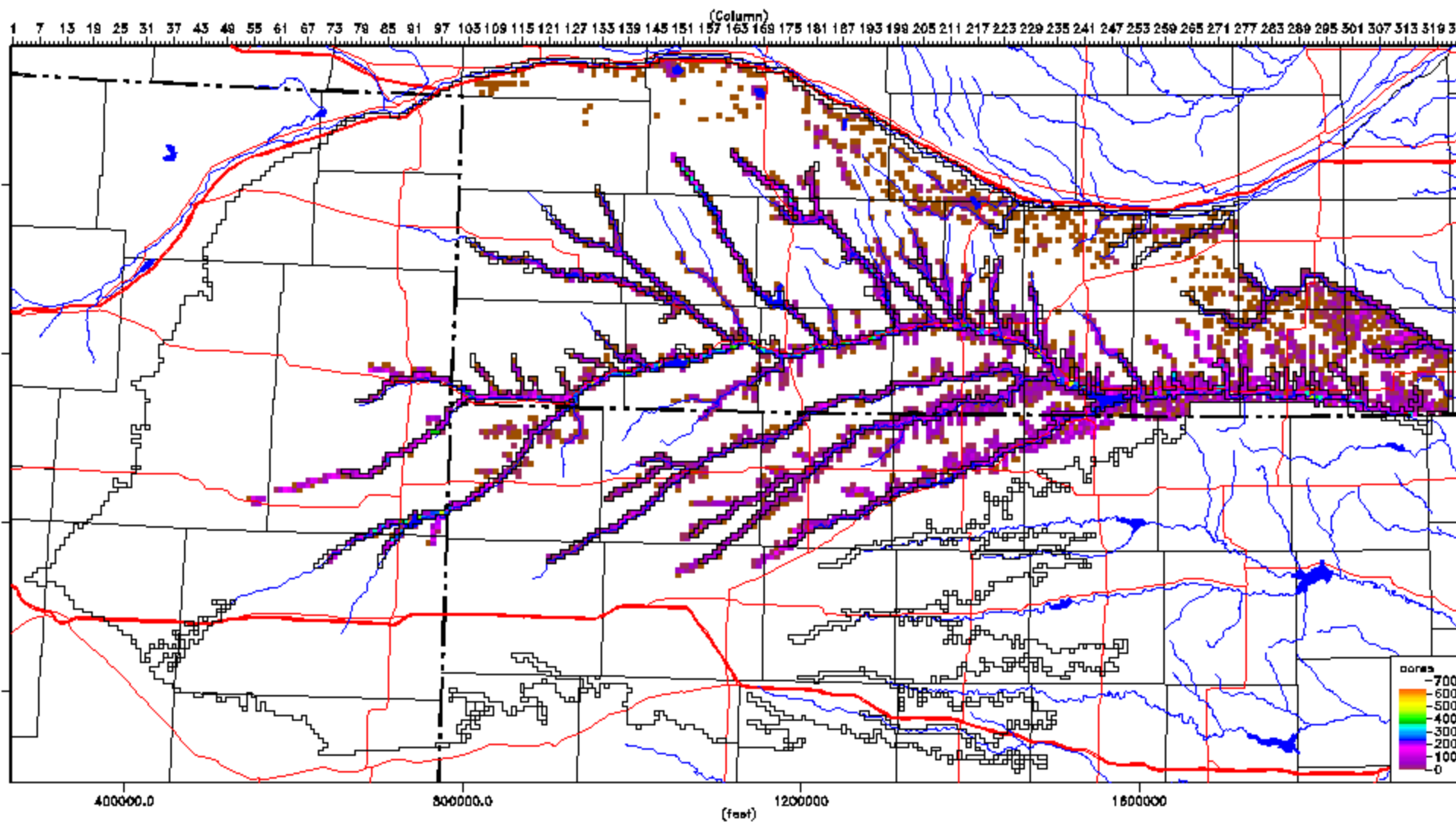
Groundwater outflow

Phreatophyte ET

- Phreatophytes = a deep-rooted plant that obtains its water from the water table
- State's determined the aerial extent of phreatophytic vegetation.
- Estimated ET potential demand by this vegetation.
- Model computes the portion of this demand that is fulfilled as a function of groundwater depth.

ET Area

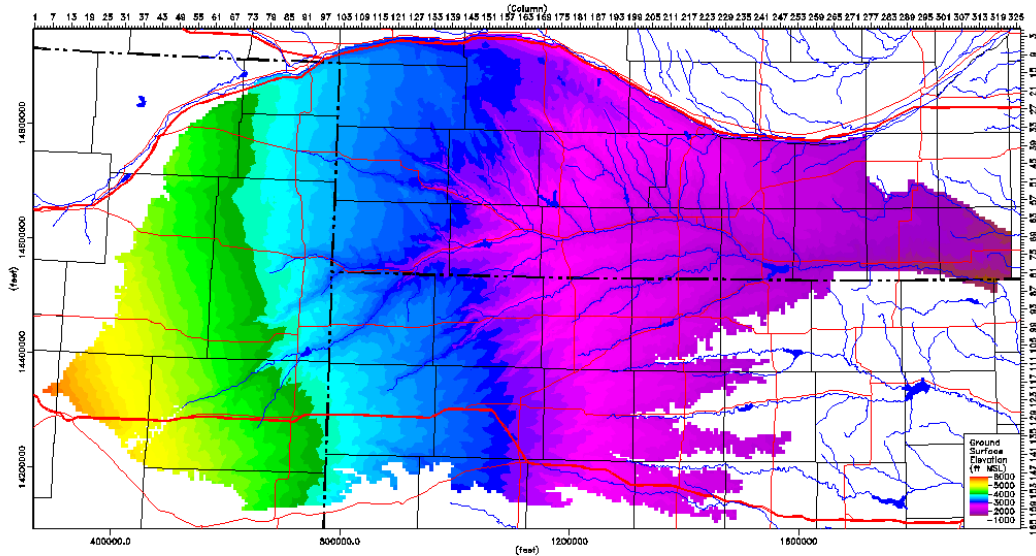
Republican River Settlement Model Version 12p



Predevelopment water levels

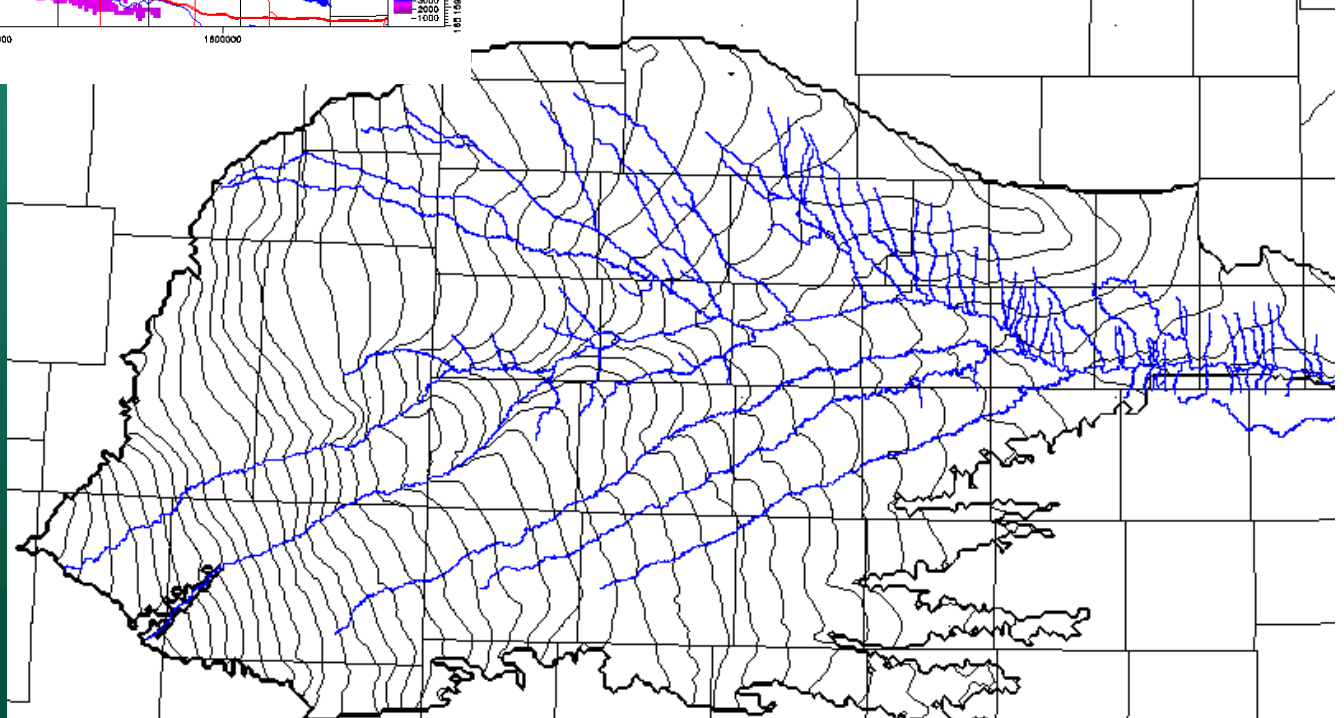


Model Ground Surface
Republican River Settlement Model Version 12p



Land surface
elevations

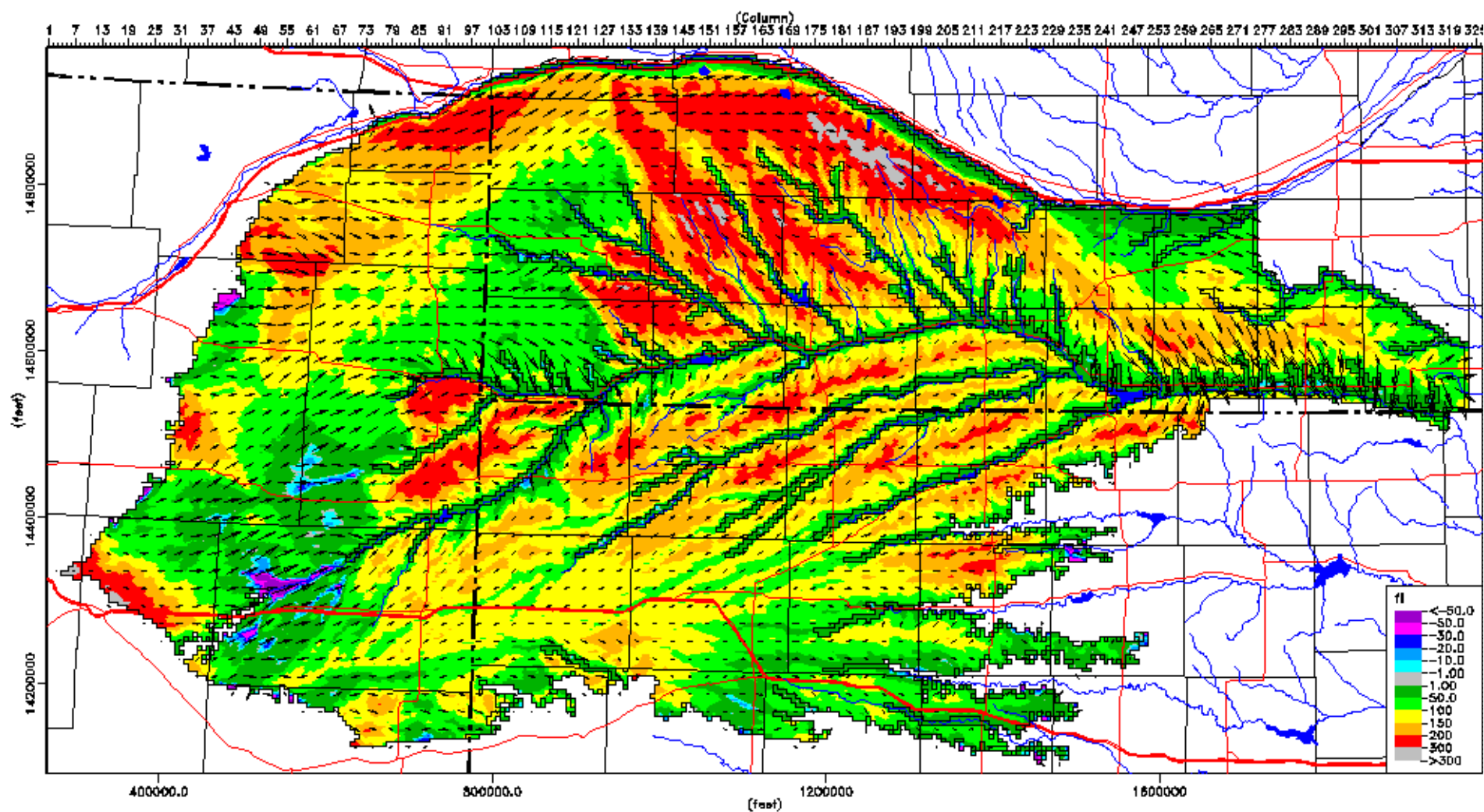
Predevelopment
top of aquifer





Steady State Depth to Water

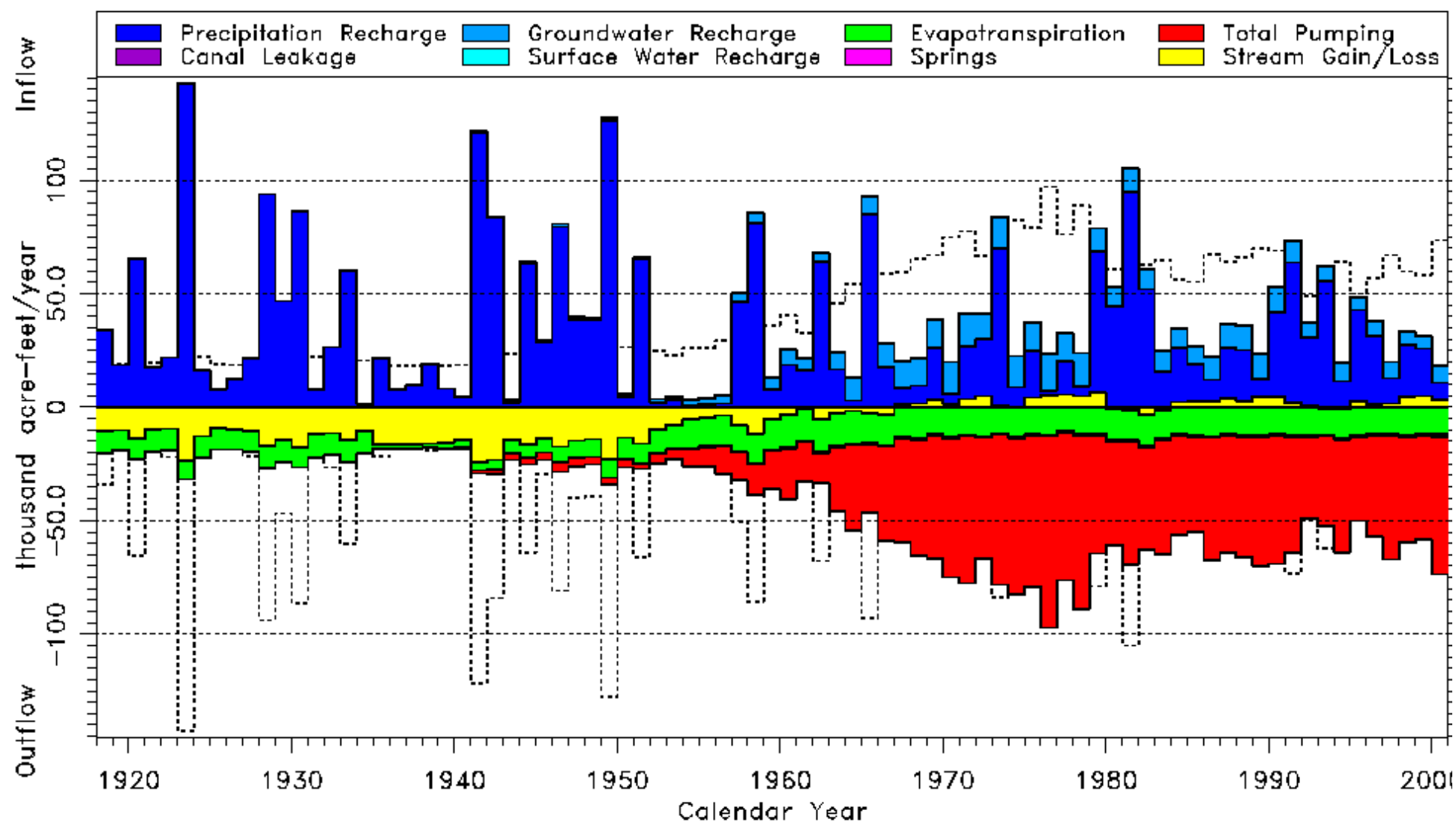
Republican River Settlement Model Version 12p





Cheyenne, KS Budget

Republican River Settlement Model Version 12p

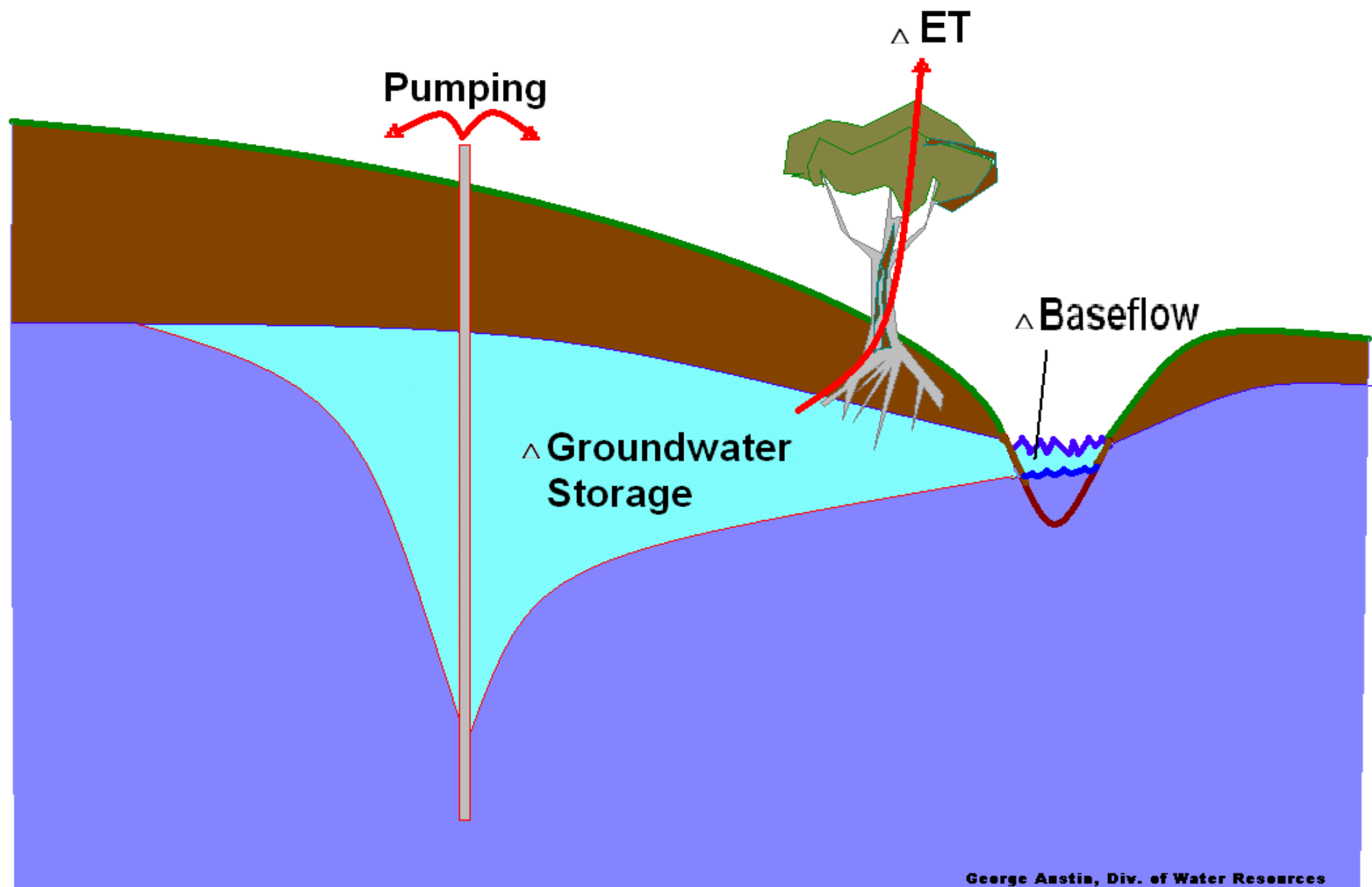


NW Kansas pre-development groundwater budget

- Inflows
 - Precipitation recharge = 198,000 AF/year
- Outflows
 - Streamflows = 55,000 AF/year
 - Drains = 50,000 AF/year
 - ET = 67,000 AF/year
- Storage change = + 33,000 AF/year

Transient period

- In the transient period, groundwater pumping, and recharge due to surface water irrigation and groundwater pumping are added.
- The model's primary purpose is to allocate impact of net pumping among storage depletion, streamflow depletion and ET salvage.



Transient stresses – groundwater pumping estimates

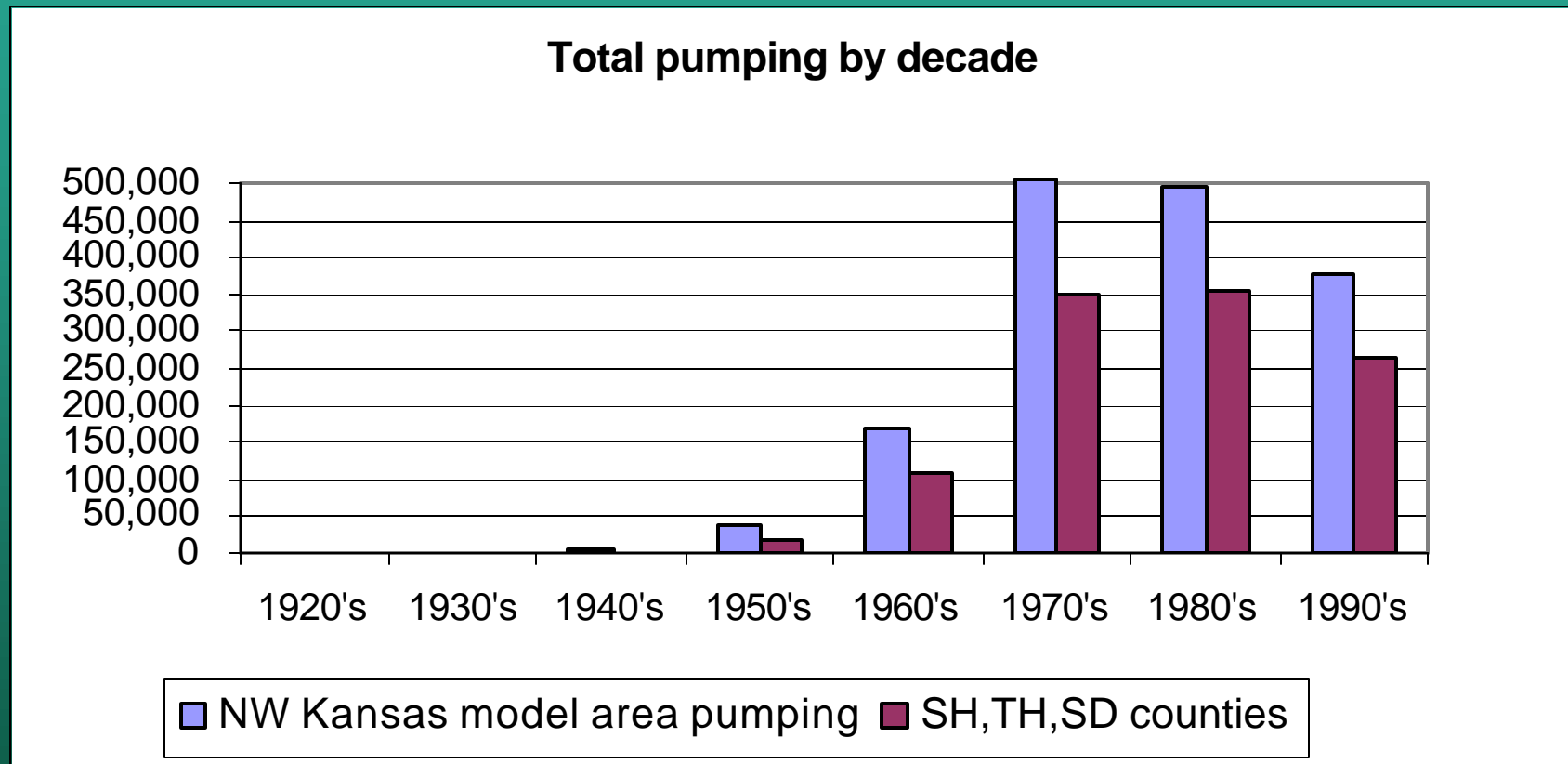
- Each state developed best pumping estimates based on existing data.
- Reviewed by the other states.

Transient stresses

Kansas groundwater pumping

- Used 1989-2000 water use reports
- Calculated crop irrigation demands (CIR) for the entire period of record
- For pre-1989 pumping estimates, used a correlation of 1989-2000 pumping and CIR and estimates of irrigated acres.
- Modifications:
 - Adjustments to 1989-2000 unmetered report
 - Adjusted for higher well capacities in the past.

Kansas groundwater pumping estimates



Transient stresses

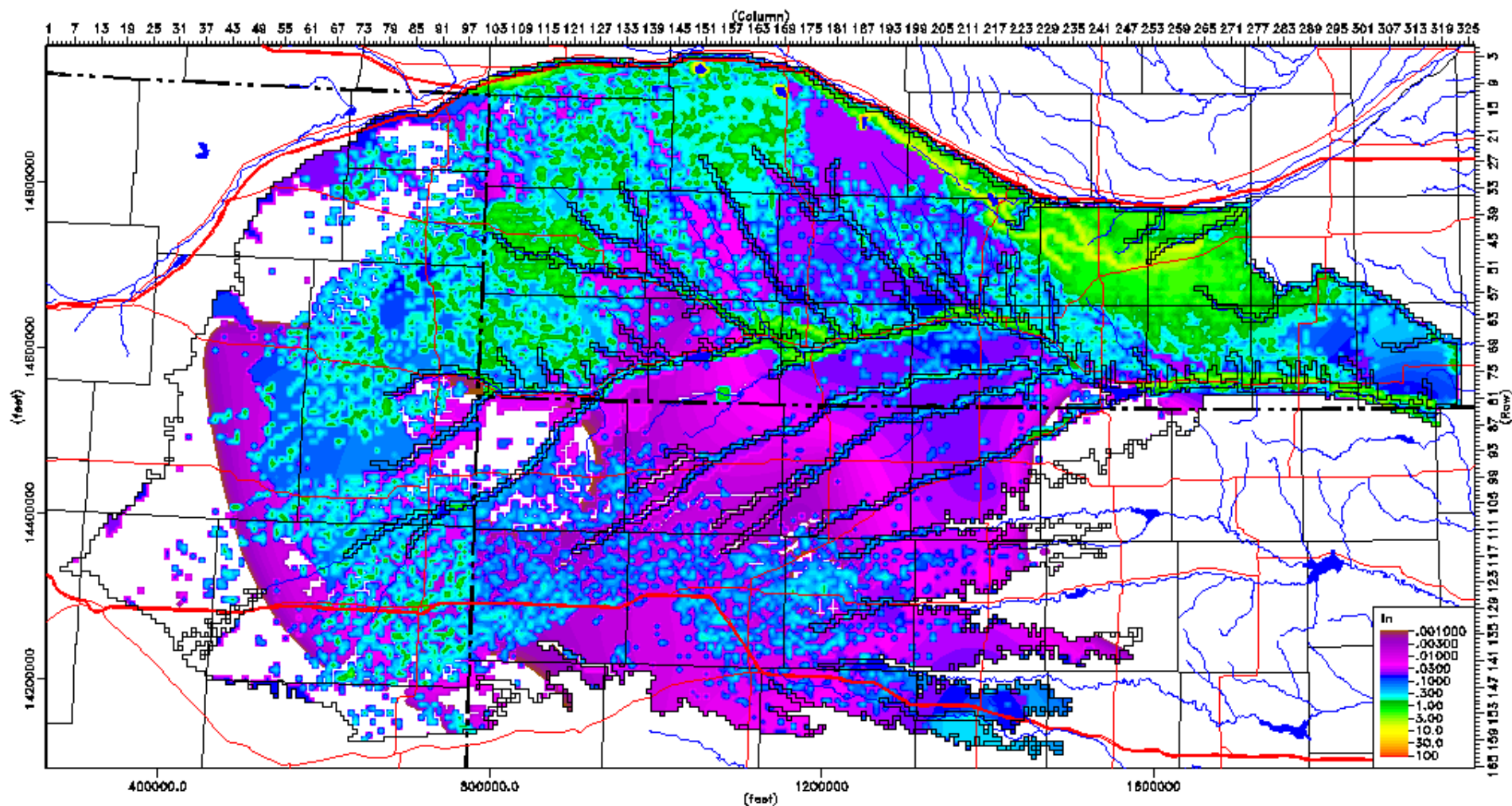
Irrigation recharge

- Each state prepared best estimates of groundwater irrigation recharge to the aquifer as well as surface water irrigation recharge.
- Typically based on best estimates of distribution of system types and efficiencies.



Recharge 7/2000

Republican River Settlement Model Version 12p



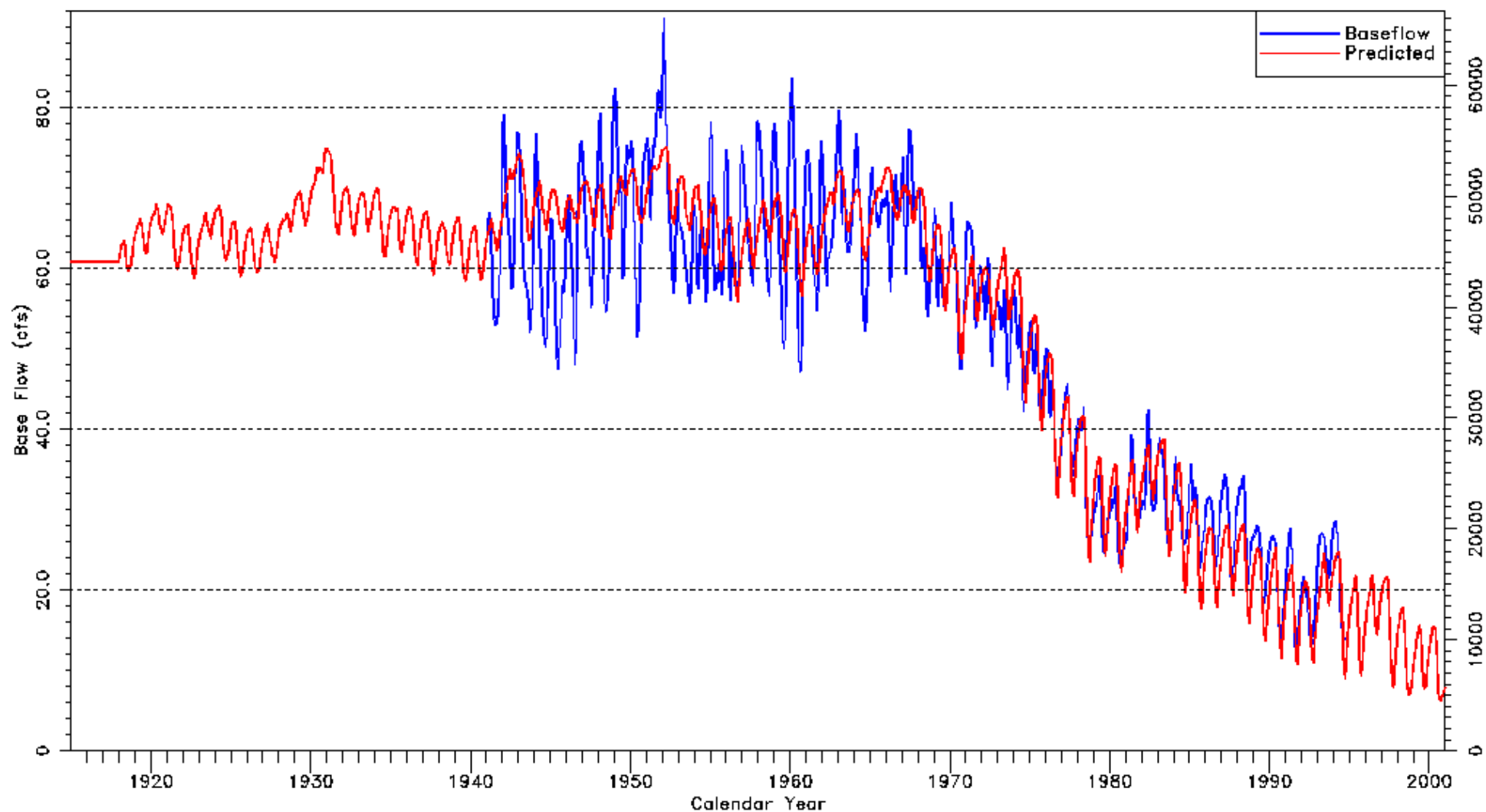
Calibration Process

- Method
 - Trial and error
 - Parameter estimation
- Targets
 - Baseflows - Annual, Winter, Summer, Monthly, and Trends
 - Water levels - elevations and trends at more than 10,000 location



Frenchman Creek near Imperial, NE

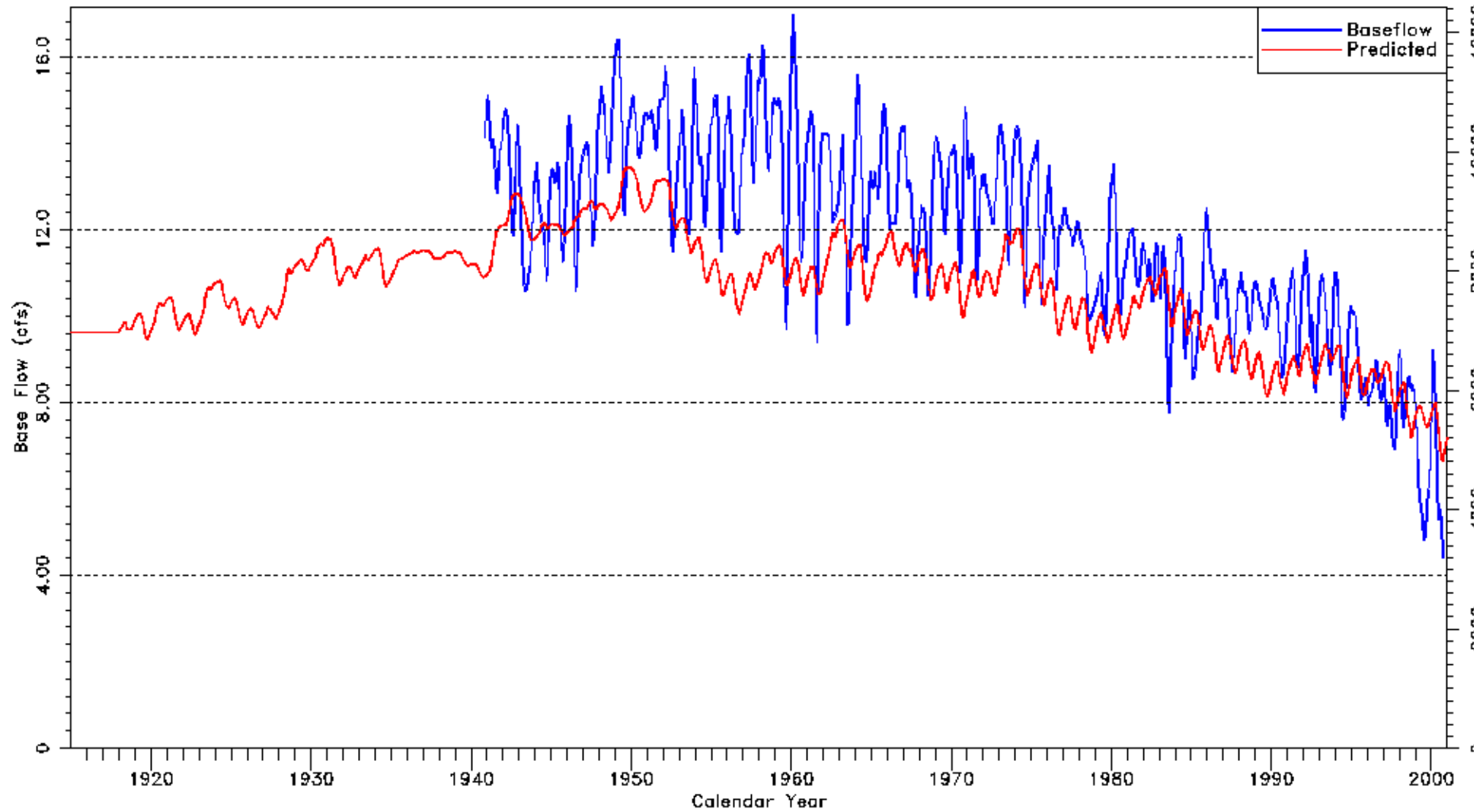
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Rock Creek at Parks, NE

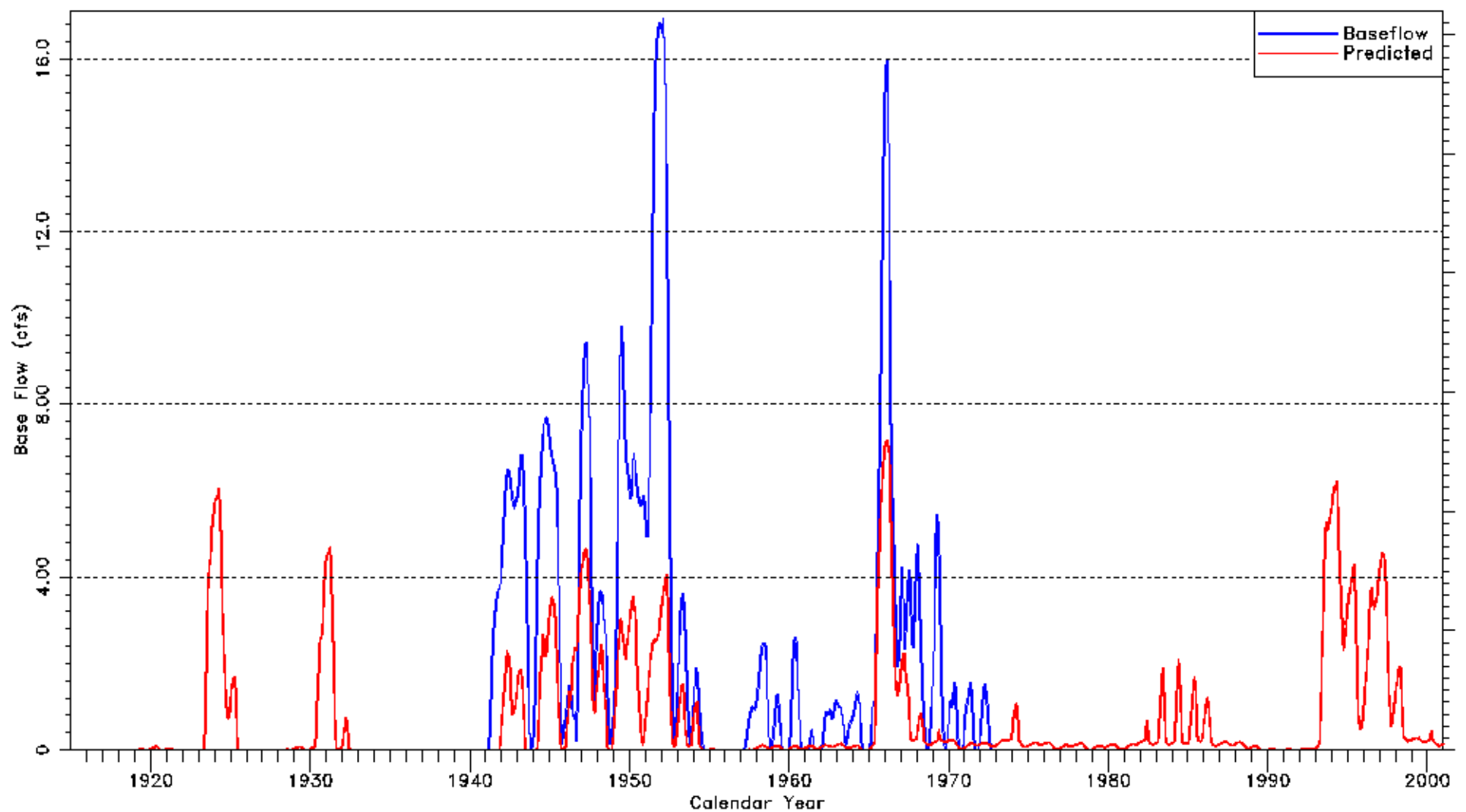
Republican River Settlement Model Version 12p



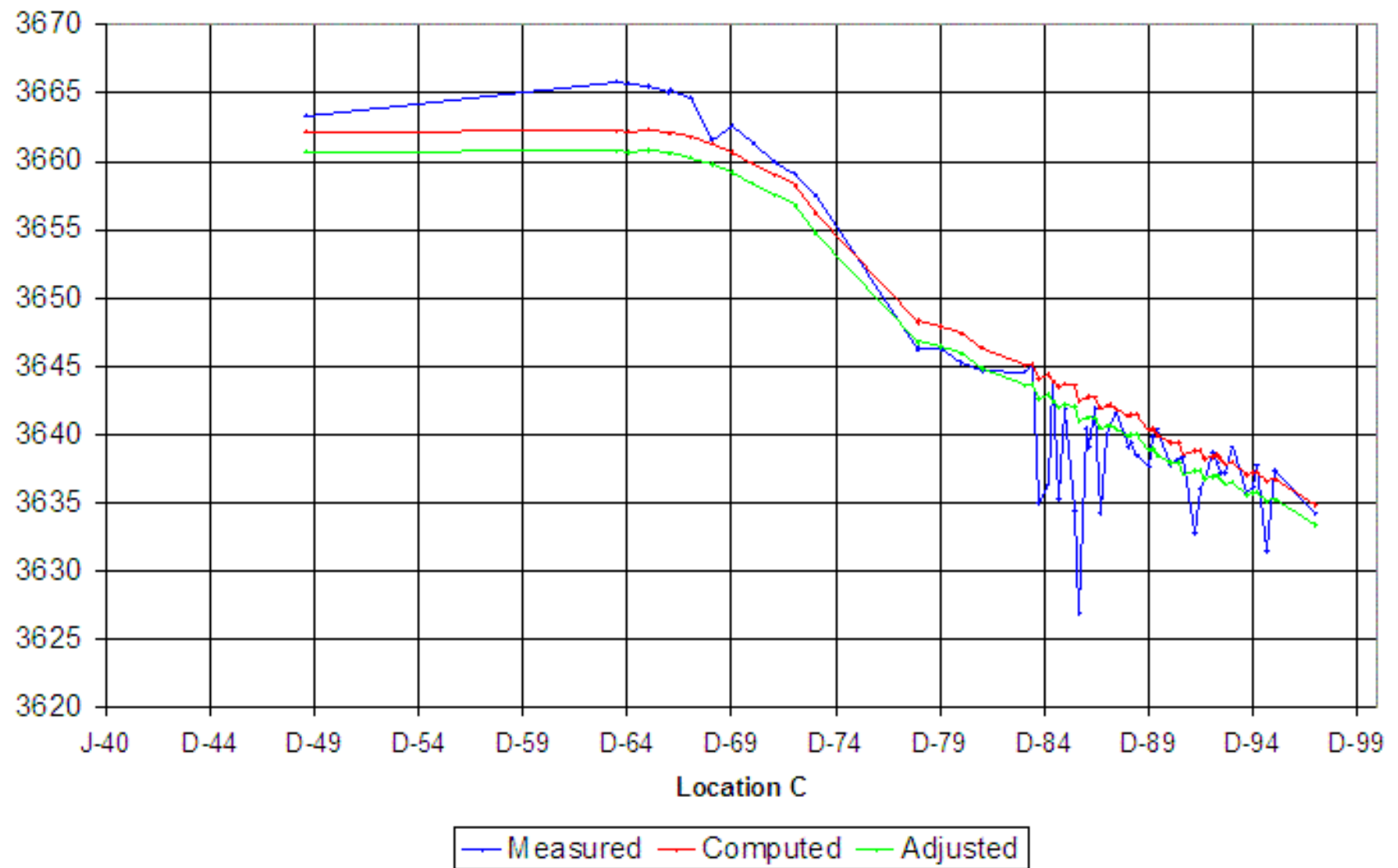


Sappa Creek near Beaver City, NE

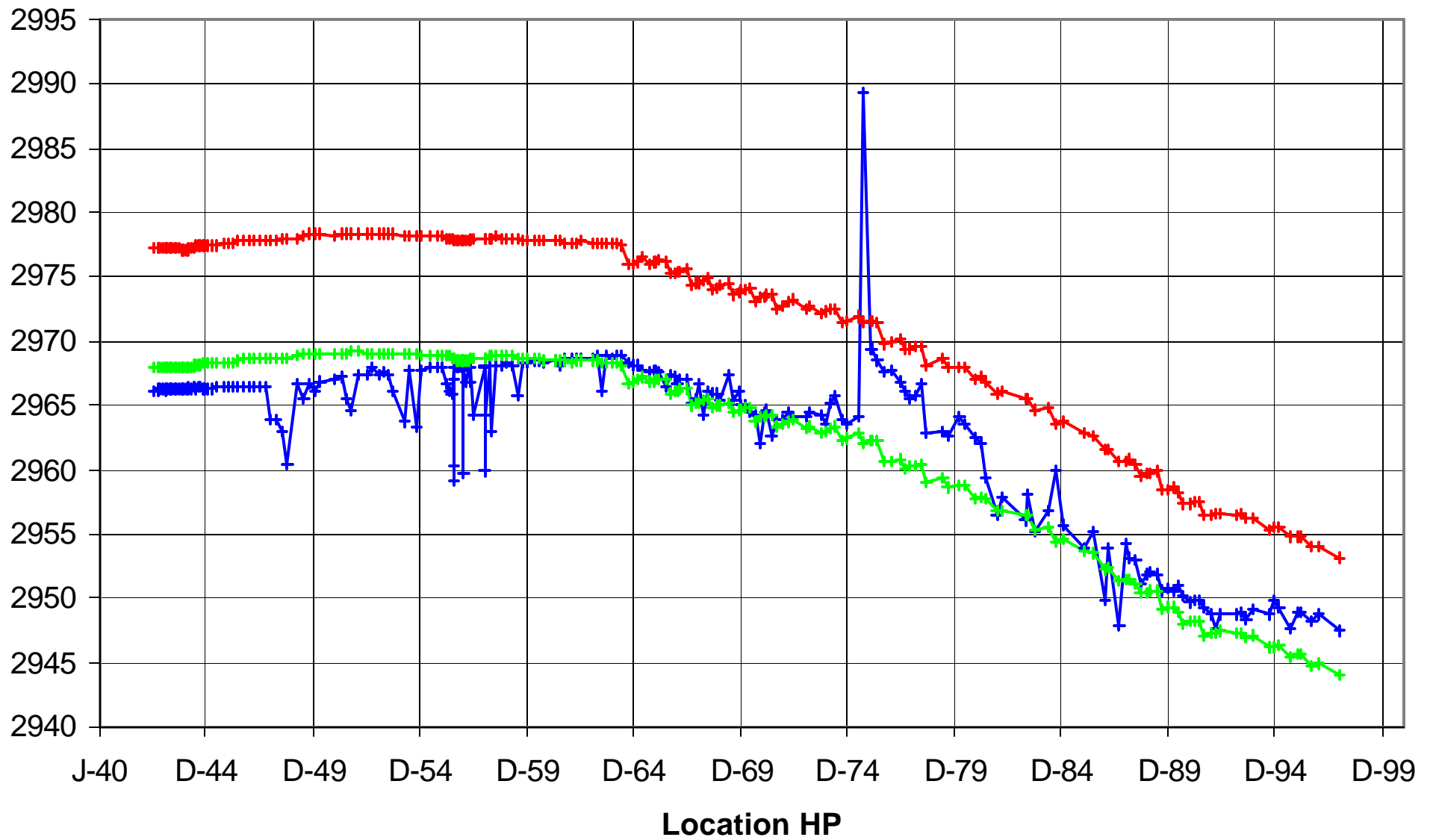
Republican River Settlement Model Version 12p



39 39 43 102 42 42 00

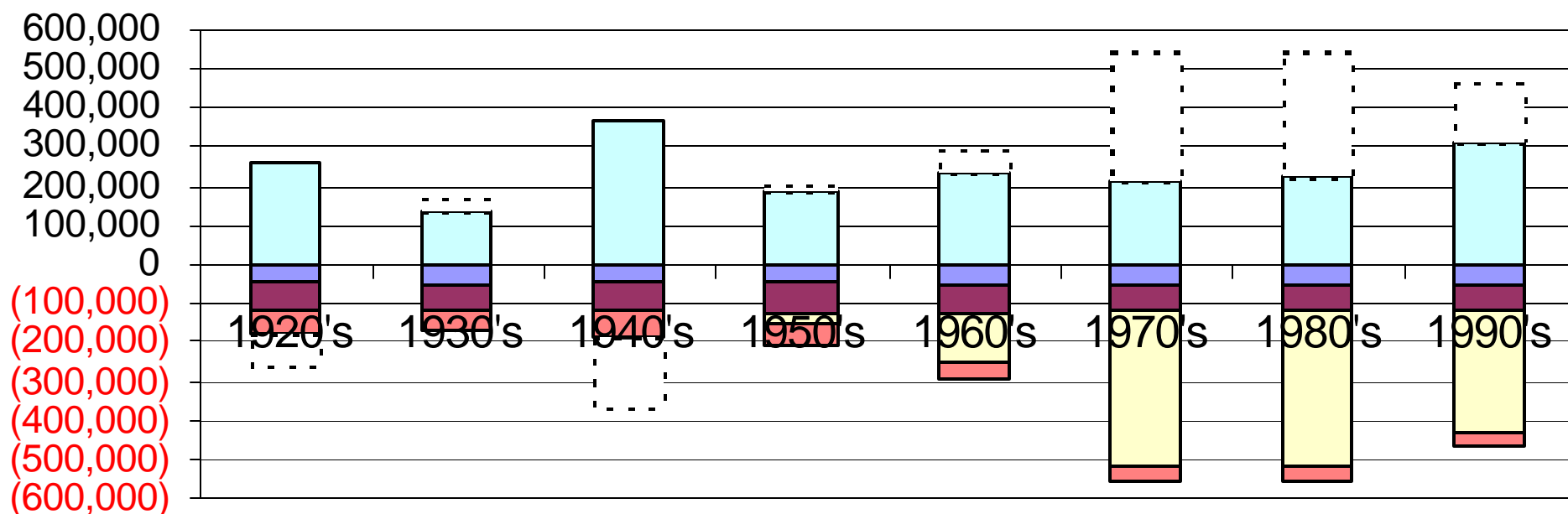


40 52 29 101 43 36 01



—+— Measured —+— Computed —+— Adjusted

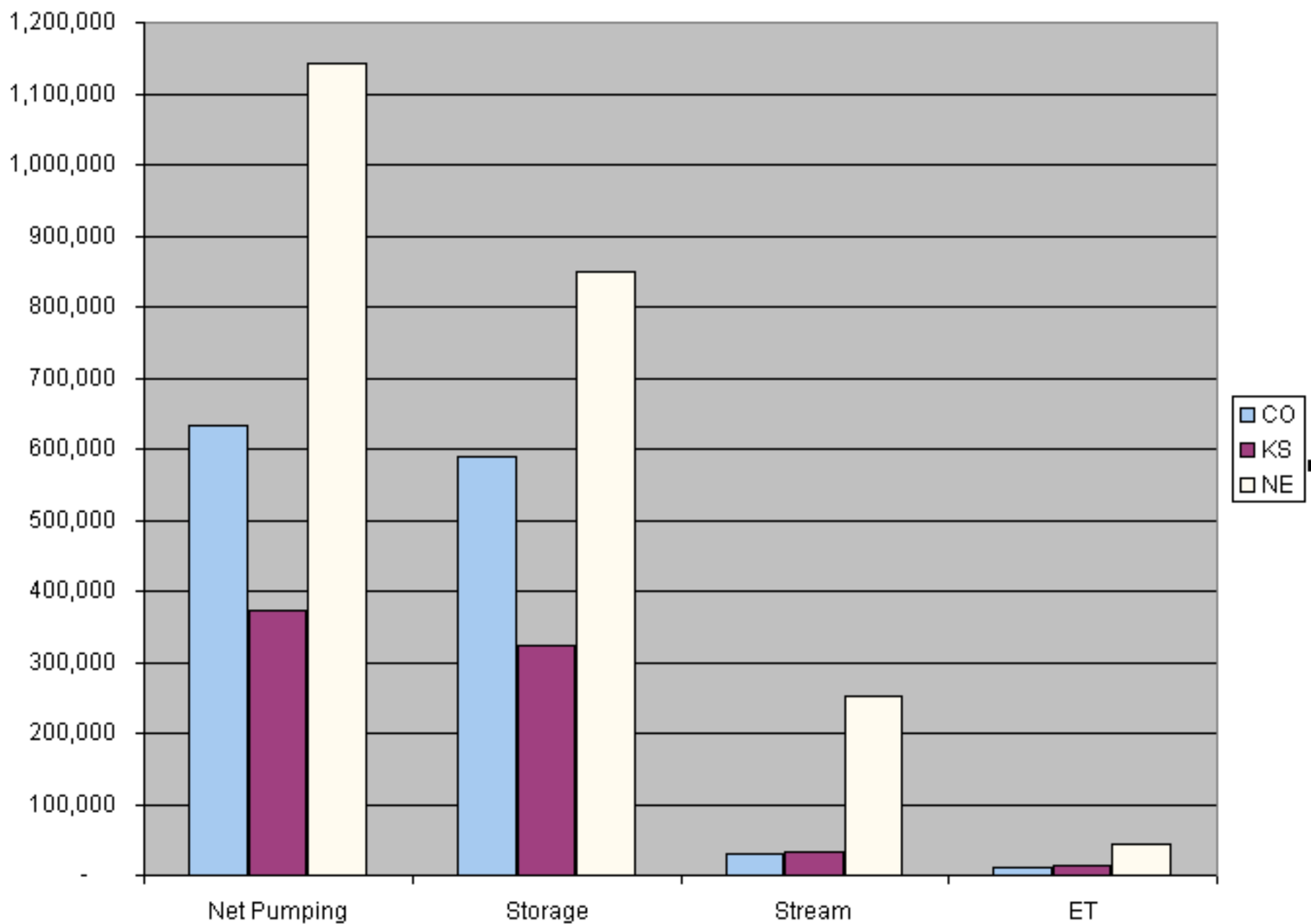
Water budget - RRCA model domain of northwest Kansas



■ Springs (O)
■ Net GW Pumping (O)
■ Stream gain/loss (I/O)

■ ET (O)
■ Precipitation Recharge (I)
--- Storage change

Net pumping Impacts



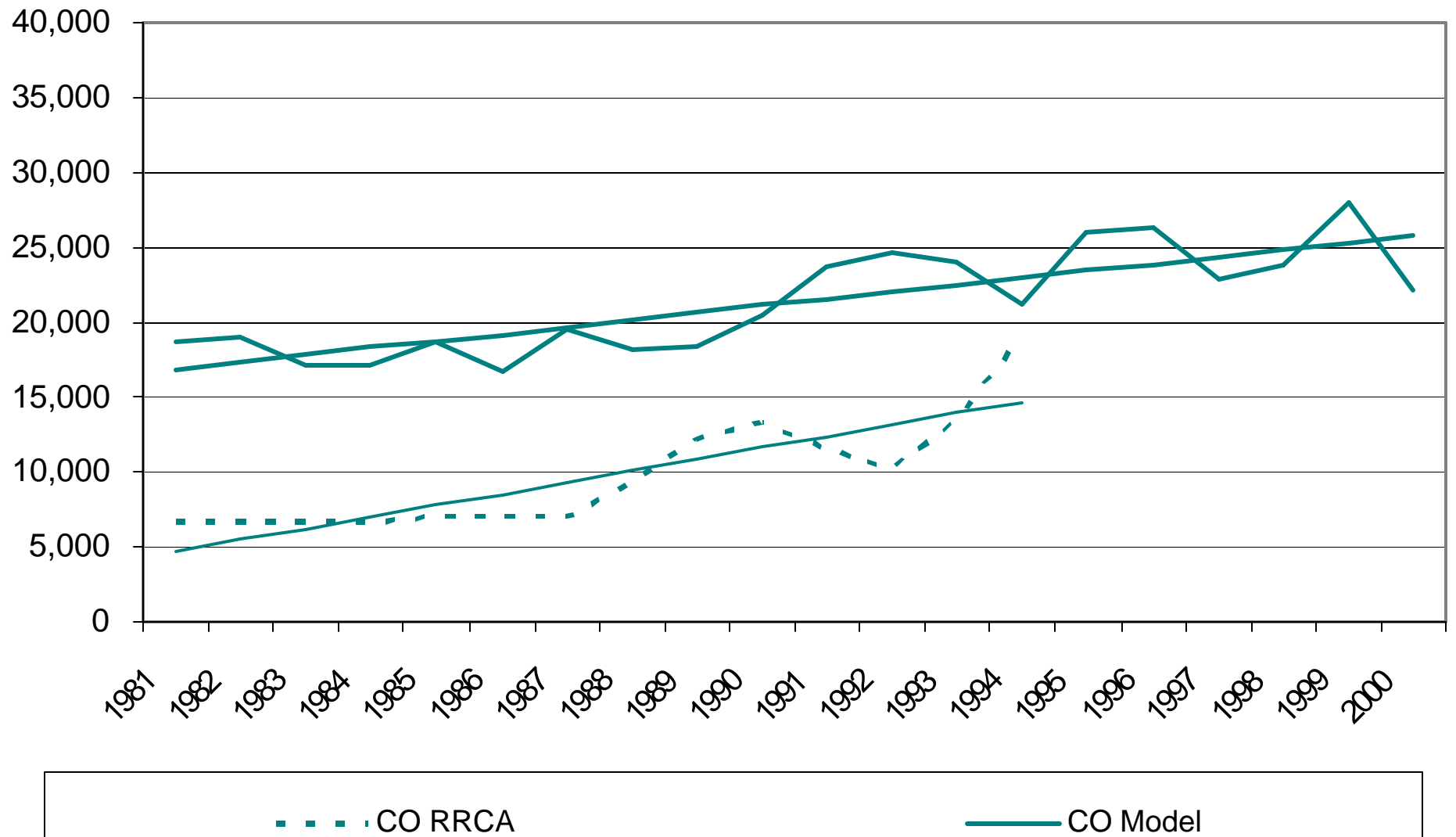
Use of RRCA groundwater model in compact accounting

- GW CU = ? in baseflows in two runs of the model, the “base” run and “no state pumping” run.
- Considers groundwater storage effects (timing of depletions).
- Credit for “ET salvage” – the reduction in phreatophyte ET with declining water levels.

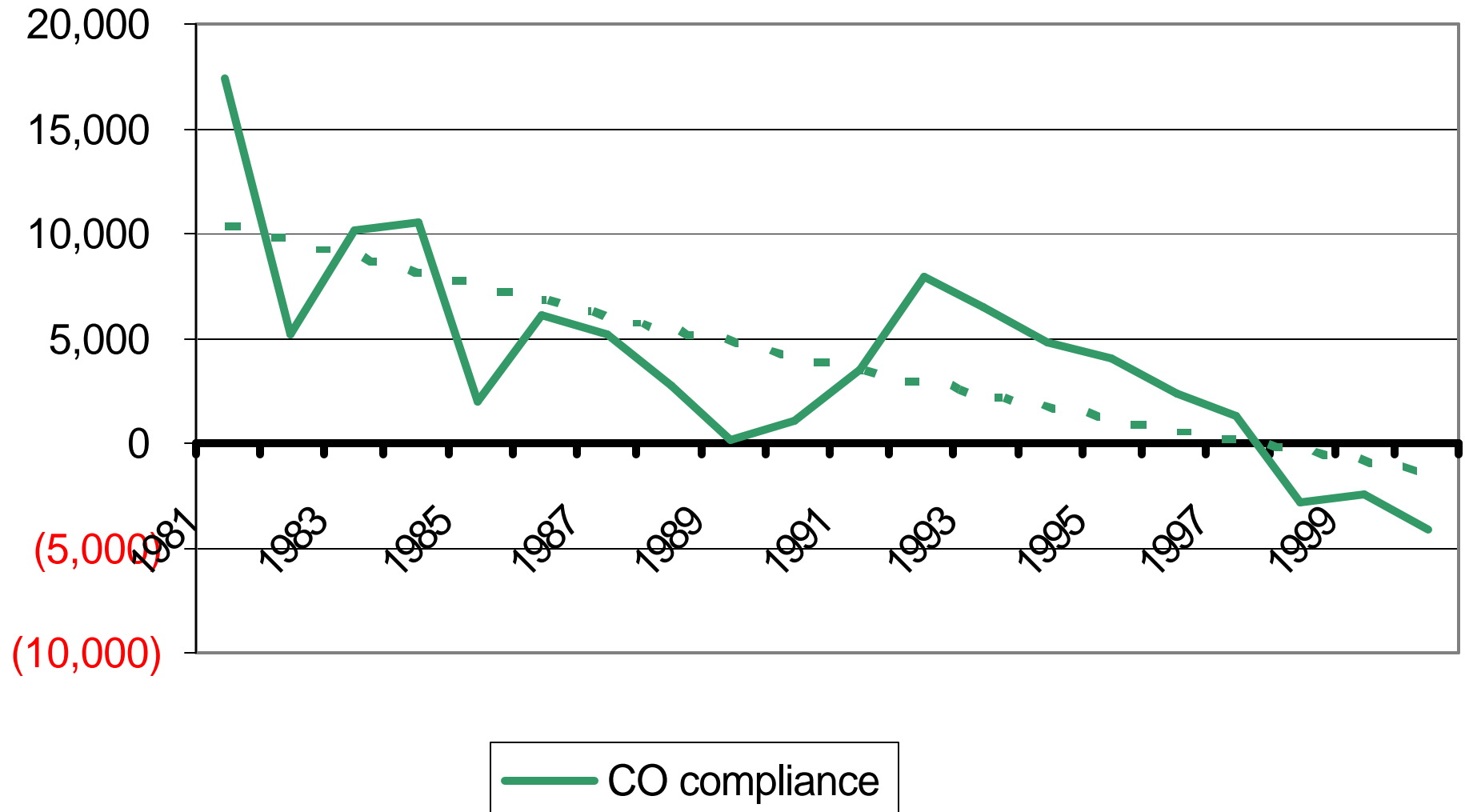
Model results in the Compact Accounting

- Kansas – impacts of Ogallala pumping relatively low as historic baseflows were low; significant ET salvage.
- Colorado – increase in estimated pumping impacts to streamflow as Ogallala impacts are significant and increasing.
- Nebraska – somewhat significant increases in streamflow impacts due to Ogallala impacts partially offset by ET salvage.

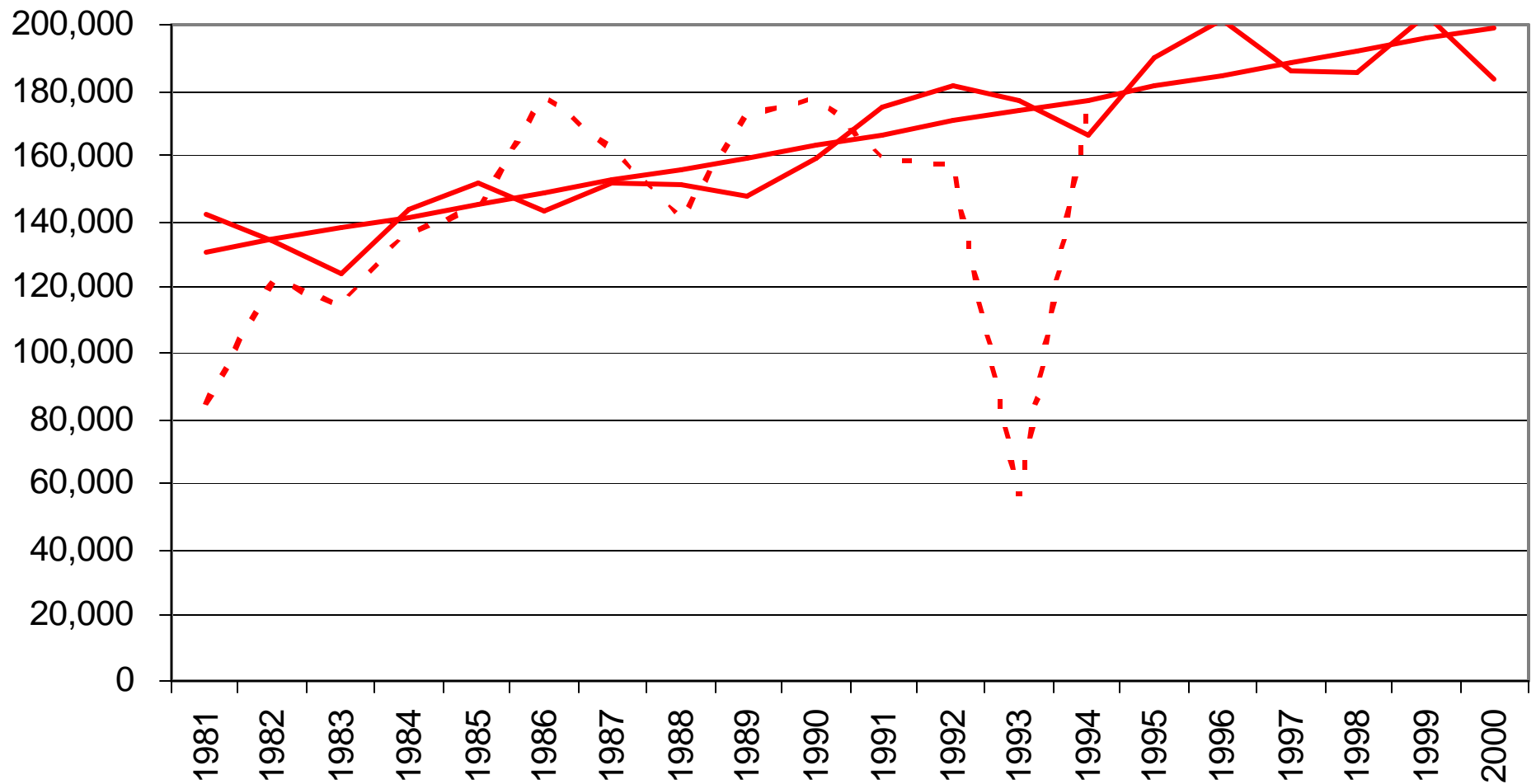
Colorado groundwater depletions



Allocation - Consumptive Use for Colorado (est.)

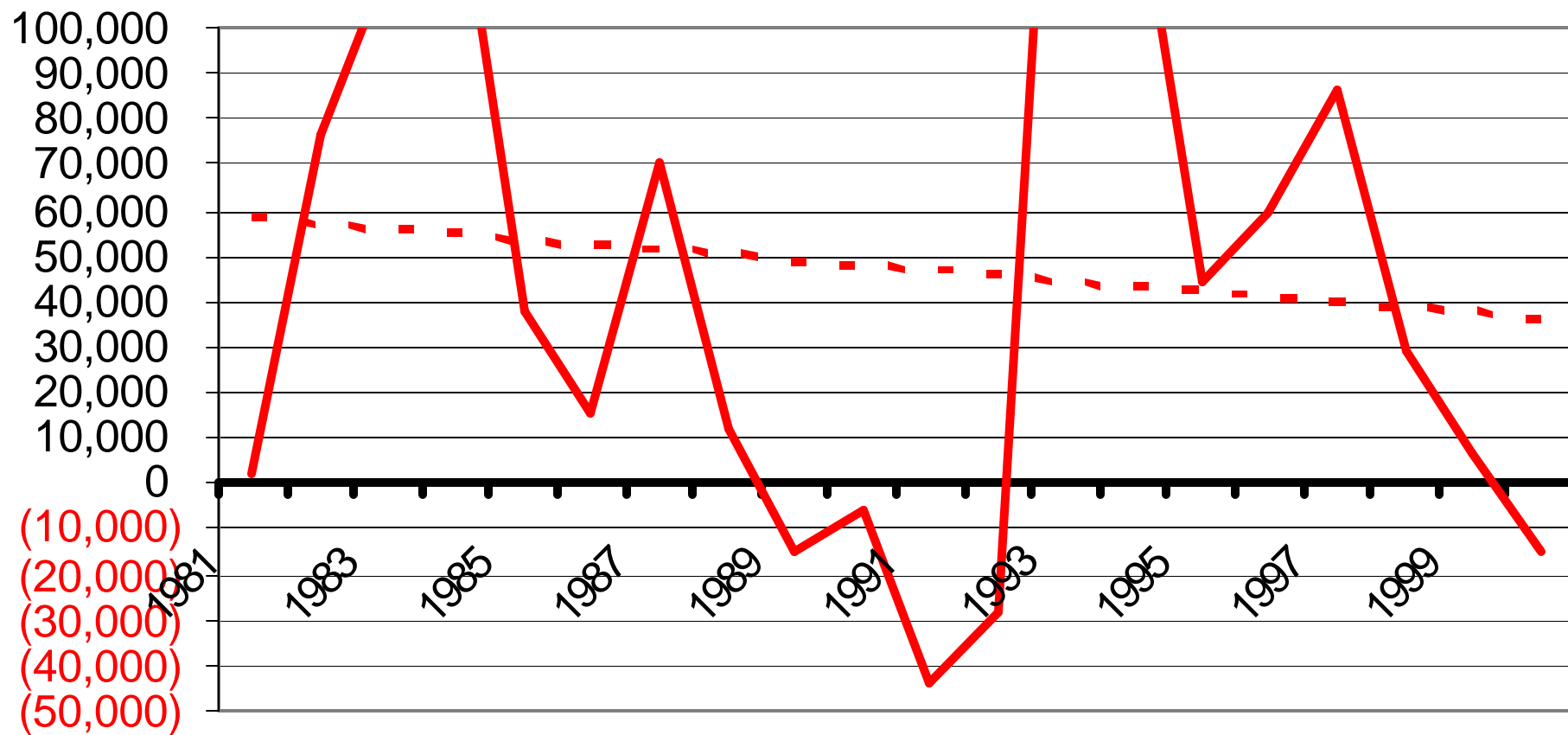


Nebraska groundwater depletions



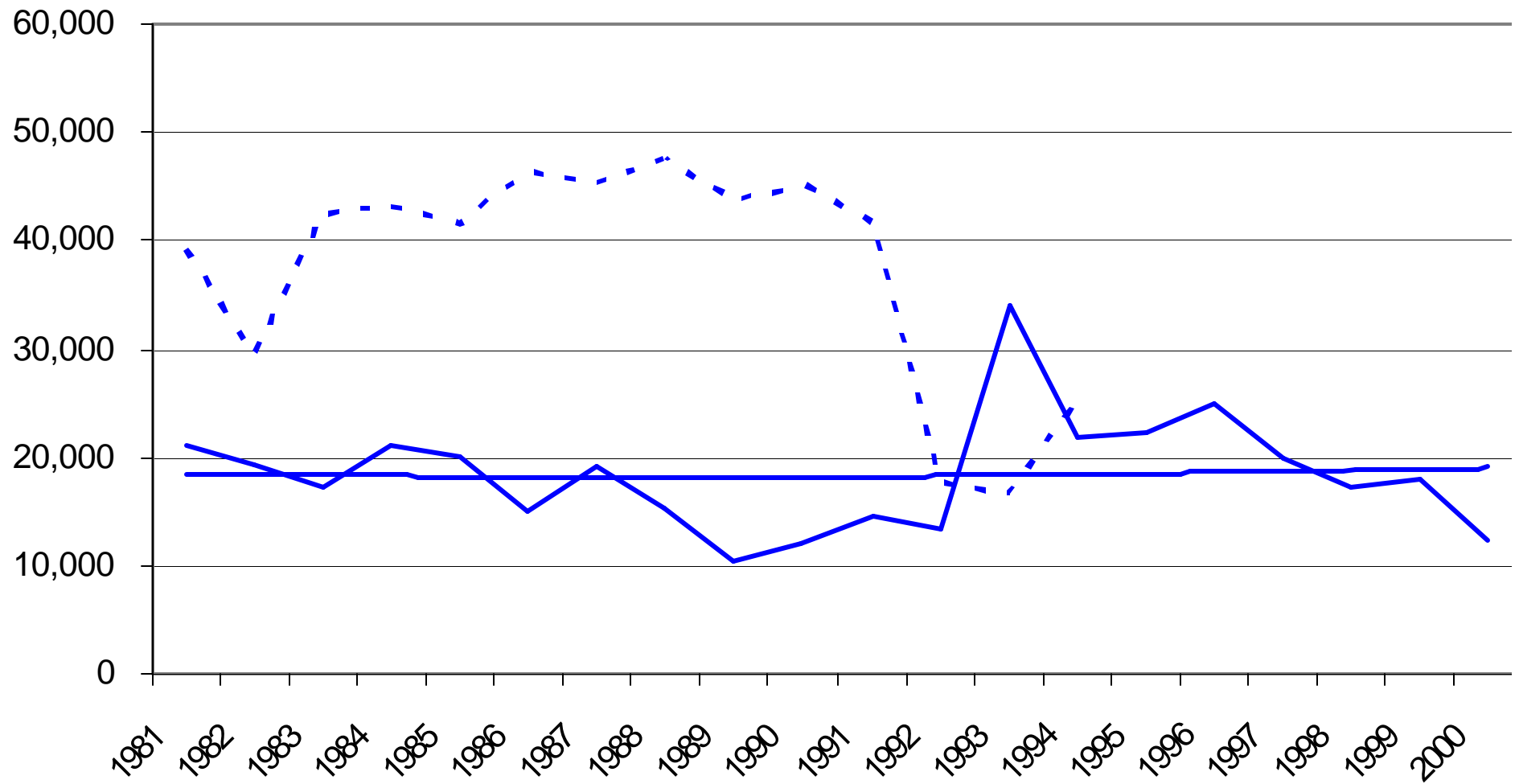
— NE Model

Allocation - Consumptive Use for Nebraska (est.)



— NE compliance

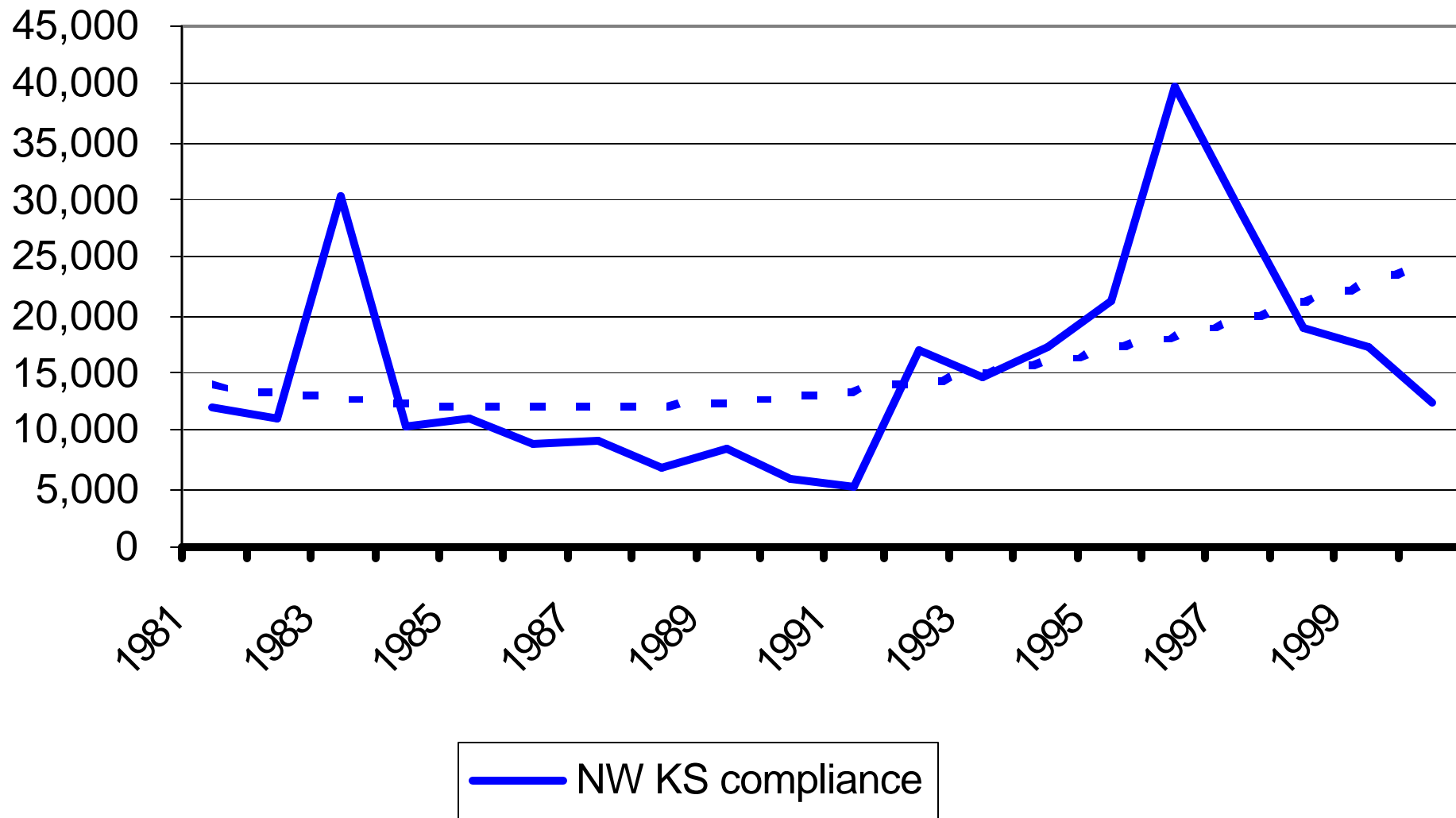
Kansas groundwater depletions



--- KS RRCA

— KS Model

Allocation - Consumptive Use for NW Kansas (est.)



How good is this model?

- Agreed to by the States for use in determination of Compact Compliance.
- Accepted by the U.S. Supreme Court. Its results are binding on the States.
- Not perfect, but good enough

Where do we go from here?

- 2001-2 data being added to the model.
- The States will annually update the model to determine compliance under the Compacts.
- States developing additional capabilities:
 - Run alternate pasts, determine sensitivities
 - Run future scenarios

Model availability

- Model, pre-processing programs, final data sets, documentation is available on-line.
- Standard Modflow 2000 with one exception. Revised model code on-line.

Groundwater Model Summary

- The RRCA groundwater model is a credible, useful, flexible tool for determining Compact compliance and for future planning to insure each of the States complies with the Compact.

